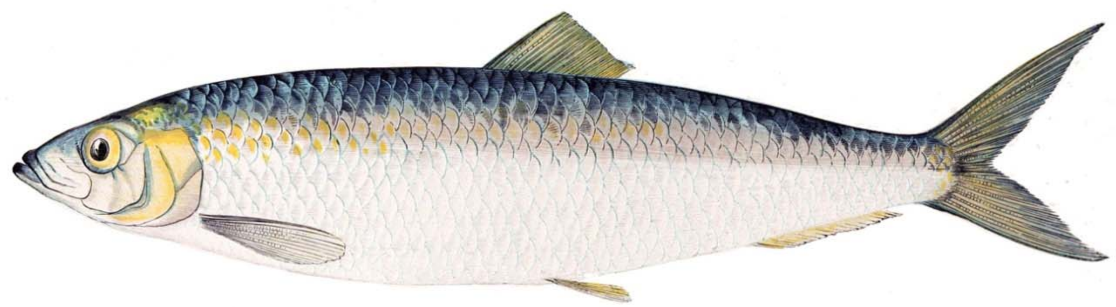
Environmental Effect Pathways between Marine Aggregate Application Areas and Atlantic Herring Potential Spawning Habitat:

Regional Cumulative Impact Assessments



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The cover image of Atlantic Herring *Clupea harengus* is taken from: Gervais H. and Boulart C., 1877. *Les Poissons de Mer. Troisième volume*. Paris.

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GLOSSARY

Abbreviation	Description	Definition
ADZ	Active Dredge Zone	A defined zone within a production licence where dredging is actually occurring
AIS	Automatic Identification System	The Automatic Identification System is an automatic tracking system used on ships and by vessel traffic services (VTS) for identifying and locating vessels by electronically exchanging data with other nearby ships, AIS Base stations and Satellites.
BGS	British Geological Survey	The BGS provides expert services and impartial advice in all areas of geoscience. Their client base is drawn from the public and private sectors both in the UK and internationally
BMAPA	British Marine Aggregate Producers Association	The representative trade body for the British marine aggregate industry
Cefas	Centre for Environment, Fisheries and Aquaculture Science	The Government's technical advisor on the marine and freshwater natural environment, fisheries science, aquaculture, mariculture and marine pollution
	The Crown Estate	Governed by an Act of Parliament acting as the property manager for the Crown (where such is not the private property of HM the Queen). It works supportively with government; in Westminster, in Scotland, Wales, Northern Ireland and at a local level regarding leasing the UKCS to allow business development

CIA	Cumulative Impact Assessment	An assessment of the additive environmental impacts resulting from dredging at more than one licence area in close proximity to other areas, impacts may develop that result from accumulation of effects from the individual licence areas. Such impacts are described as cumulative. As part of the CIA process in this study see also in-combination effects
	Draghead	Equipment on the end of a dredge pipe that is in contact with the seabed during dredging
	Dredge Pipe	Equipment through which water and sediment is drawn from the seabed to the dredger
	Dredger	A generic term describing a ship capable of removing sediment from the seabed
EIA	Environmental Impact Assessment	Process by which the effects of a plan or project on the environment, and its constituent parts, is determined
EIA Directive	Environmental Impact Assessment Directive 2011/92/EU	The Directive from the European Commission that requires an EIA to be undertaken for certain projects
EMS	Electronic Monitoring System	The 'black box' monitoring system on board a dredger that records the vessel's position and activity to ensure that dredging is only undertaken within permitted zones
	Entrainment	The direct uptake of benthic organisms and fish by the draghead during dredging operations
HAWG	Herring Assessment Working Group	The ICES Working Group on Herring Assessment for the Area South of 62°N (HAWG) provides scientific advice on the Atlantic Herring stocks in the North Sea and the adjacent areas spanning from the Celtic Sea to the Western Baltic

ICES	The International Council for the Exploration of the Sea	ICES is a leading multidisciplinary scientific forum for the exchange of information and ideas on all aspects of marine sciences pertaining to the North Atlantic, including the adjacent Baltic Sea and North Sea, and for the promotion and coordination of marine research by scientists within its member nations
IFCA	Inshore Fisheries and Conservation Authority	The Government's statutory agencies tasked with managing inshore fisheries and the sustainable use of the UK seas at a regional scale. There are 10 regional IFCAs in total
IHLS	International Herring Larvae Survey	The International Herring Larvae Survey is coordinated by ICES and conducted annually by vessels from the Netherlands and Germany. The survey gives inference on the total biomass of autumn spawning Atlantic Herring in the North Sea
	In-combination effects	Additive impacts resulting from marine aggregate dredging and other marine activities such as fishing, dredge disposal, cabling and pipelines etc.
JNCC	The Joint Nature Conservation Committee	The Government's statutory advisor on the marine natural environment from 12 to 200 nautical miles and UK territories
	0-ringer	Herring larvae of <10 mm size (for reference in this report) generally with yolk-sac still attached and associated with the benthos; or just post yolk-sac and liberating into the plankton

MAREA	Marine Aggregate Regional Environmental Assessment	Assessment of marine aggregate extraction environmental effects at a regional sea scale considering cumulative effects. It is a non-statutory instrument
	Marginal Habitat Sediment Class	In the context of this report this is the sediment division/unit represented by gravelly Sand which Atlantic Herring may select as part of their spawning habitat requirements. This sediment class has adequate sediment structure but is less favourable than preferred habitat – see also *Suitable* description
Marine Aggregate EIA WG	Marine Aggregate Environmental Impact Assessment Working Group	A consortium of marine environmental consultants (engaged in production of Environmental Statements or technical reports for marine aggregate production companies) consisting of: ABPmer Ltd; ERM Ltd; Fugro EMU Ltd; MarineSpace Ltd; and Marine Ecological Surveys Ltd
MMO	Marine Management Organisation	The executive non-departmental public body responsible for most activities licensed within the marine environment
MWR	Marine Works (Environmental Impact Assessment) Regulations (as amended 2011)	The domestic legislation that transposes the EIA Directive into UK law and applies to marine licence applications for marine aggregate extraction licences
NE	Natural England	The Government's statutory advisor on the English natural environment out to 12 nm

NOAA	The National Oceanic and Atmospheric Administration	A scientific agency within the United States (of America) Department of Commerce focused on the conditions of the oceans and the atmosphere. Amongst other duties NOAA charts seas and skies, guides the use and protection of ocean and coastal resources, and conducts research to improve understanding and stewardship of the environment
PIZ	Primary Impact Zone	The zone within which impacts resulting from the passage of the draghead over the seabed surface occur – also known as the direct impact zone
	Prime Habitat Sediment Class	Ideal sediment structure that supports Atlantic Herring spawning activity – see also *preferred habitat sediment class*
	Preferred Habitat Sediment Class	In the context of this report these are the sediment divisions/units represented by Gravel and sandy Gravel which Atlantic Herring favourably select as part of their spawning habitat requirements. It should be noted that other physical, chemical and biotic factors contribute to the overall definition of potential spawning habitat – see also *Prime* and *Sub-prime* descriptions.
RAG	Regulatory Advisors Group	A group of statutory and technical advisors to the Regulator (the MMO) regarding marine aggregate extraction operations and impacts. Members include Natural England, Cefas, the JNCC and English Heritage

REC	Regional Environmental Characterisation	Broadscale description at a regional sea scale of the environment associated with marine aggregate extraction licences
SIZ	Secondary Impact Zone	The footprint of effects arising as a result of the proposed dredging activity not associated with the PIZ – also known as the indirect impact zone
	Sub-prime Habitat Sediment Class	Atlantic Herring habitat sediment which has acceptable sediment structure and supports spawning activity – see also *preferred habitat sediment class*
	Suitable Habitat Sediment Class	Atlantic Herring habitat sediment which has adequate sediment structure but is likely to only support low density of spawning activity – see also *marginal habitat sediment class*
	United Kingdom Territorial Waters	The region of waters surrounding the United Kingdom, in which the country claims sovereign rights
	Unsuitable Habitat Sediment Class	Seabed sediment classes which have inadequate sediment structure to be chosen by Atlantic Herring for spawning grounds. These are all Folk sediment classes excluding Gravel, part sandy Gravel and part gravelly Sand
VMS	Vessel Monitoring System	Vessel monitoring systems are used in commercial fishing to allow fisheries regulatory organizations to monitor the position, time at a position, and course and speed of fishing vessels. They are usually deployed on fishing vessels >15 m length

Wider Regional Sea Area	The area considered to be relevant to this assessment for Atlantic Herring, ranging from the Firth of Forth south, to an area just west of the Isle of Wight and out to the boundary of UK territorial waters

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1. Introduction

This report and the assessments that it presents are intended to supplement the respective Marine Aggregate Regional Environmental Assessment (MAREA) reports that have been commissioned by the UK marine aggregate production companies (EMU Ltd, 2012a, 2012b; ERM Ltd, 2010, 2012). A strategic review of all the MAREAs was conducted by MarineSpace Ltd on behalf of the British Marine Aggregate Producers Association (BMAPA) (MarineSpace Ltd, 2013a, 2013b, 2013c, 2013d). Within all the MAREA reports Atlantic Herring *Clupea harengus* potential spawning habitat was consistently identified as requiring assessment within individual application Environmental Statements (ESs). Considering the universal nature of the issue MarineSpace advised that Atlantic Herring potential spawning habitat should be characterised and investigated at a regional strategic level through cumulative impact assessment (MarineSpace Ltd, 2013a, 2013b, 2013c, 2013d).

There are a number of marine aggregate licence renewals and new applications expected within the next 2-18 months – many of which are business critical to the operators concerned, and of strategic importance to the UK marine aggregates industry as a whole. To aid the efficient delivery of marine aggregate licence applications under the Marine Works Regulations (as amended 2011) (MWR), ABPmer Ltd, ERM Ltd, Fugro EMU Ltd, MarineSpace Ltd, and Marine Ecological Surveys Ltd (a consortium of marine environmental consultants engaged in the production of ESs or technical reports for marine aggregate production companies; henceforth referred to as the Marine Aggregate Environmental Impact Assessment Working Group (EIA WG)) have been engaged by BMAPA and The Crown Estate, on behalf of the marine aggregate production companies, to facilitate the delivery of regional cumulative impact assessments (CIAs).

The metrics, parameters and thresholds describing the environmental characteristics of Atlantic Herring potential spawning habitat, and the screening exercise, spatial analysis and CIAs presented in this report, are intended to generate information of sufficient resolution and confidence to support an EIA for any marine aggregate licence application under the MWR application process.

The methodology used to develop the screening assessment procedure has evolved and been agreed through discussions (and a workshop) held by the Marine Aggregate EIA WG (Reach *et al.*, 2013; Appendix A). The method statement builds upon consultation and advice provided by the Marine Management Organisation (MMO) and the Regulatory Advisors Group (RAG) (MMO, 2013a).

1.1. Atlantic Herring *Clupea harengus* Linnaeus, 1758

Atlantic Herring *Clupea harengus* spawning grounds and areas appear to have a relatively wide range of seabed habitat and broader environmental requirements and parameters (such as oxygenation of sediments and micro-scale seabed morphological features e.g. ripples and ridges), making fine-scale mapping of these habitats difficult (de Groot, 1979, 1980, 1986, 1996; Bowers, 1980; Rankine, 1986; Aneer, 1989; Blaxter, 1990; Morrison *et al.*, 1991; Heath *et al.*, 1997; Maravellias *et al.*, 2000; Maravellias, 2001; Mills *et al.*, 2003; Skaret *et al.*, 2003; Geffen, 2009; Nash *et al.*, 2009; Greenstreet *et al.*, 2010; Payne, 2010; ECA and RPS Energy, 2010a, 2010b, 2011; ICES, 2012). Habitat and water quality changes can affect the spawning and recruitment success of sensitive fish species. Demersal or benthic spawning species may be especially sensitive to the effects of activities which interact directly with the seabed, or result in changes to turbidity and subsequent settling and transportation of sediment particles. Atlantic Herring are such a species, reported as being sensitive to disturbance to spawning habitat from direct removal, or to alteration of particle size distribution (fining) of the sediments with potential to act as spawning habitat (de Groot, 1980, 1986; Aneer, 1989; Morrison *et al.*, 1991; Geffen, 2009; ICES, 2012).

Due to the known environmental effects associated with marine aggregate extraction operations, the resources targeted (sands and gravels) and the overlap with known Atlantic Herring spawning population ranges it is likely that there are effect-receptor pathways. Quantification of these pathways and footprints and assessment of magnitude of effects will set context and allow environmental assessment for upcoming marine aggregate licence applications, alone and cumulatively.

1.2. Aims and Objectives

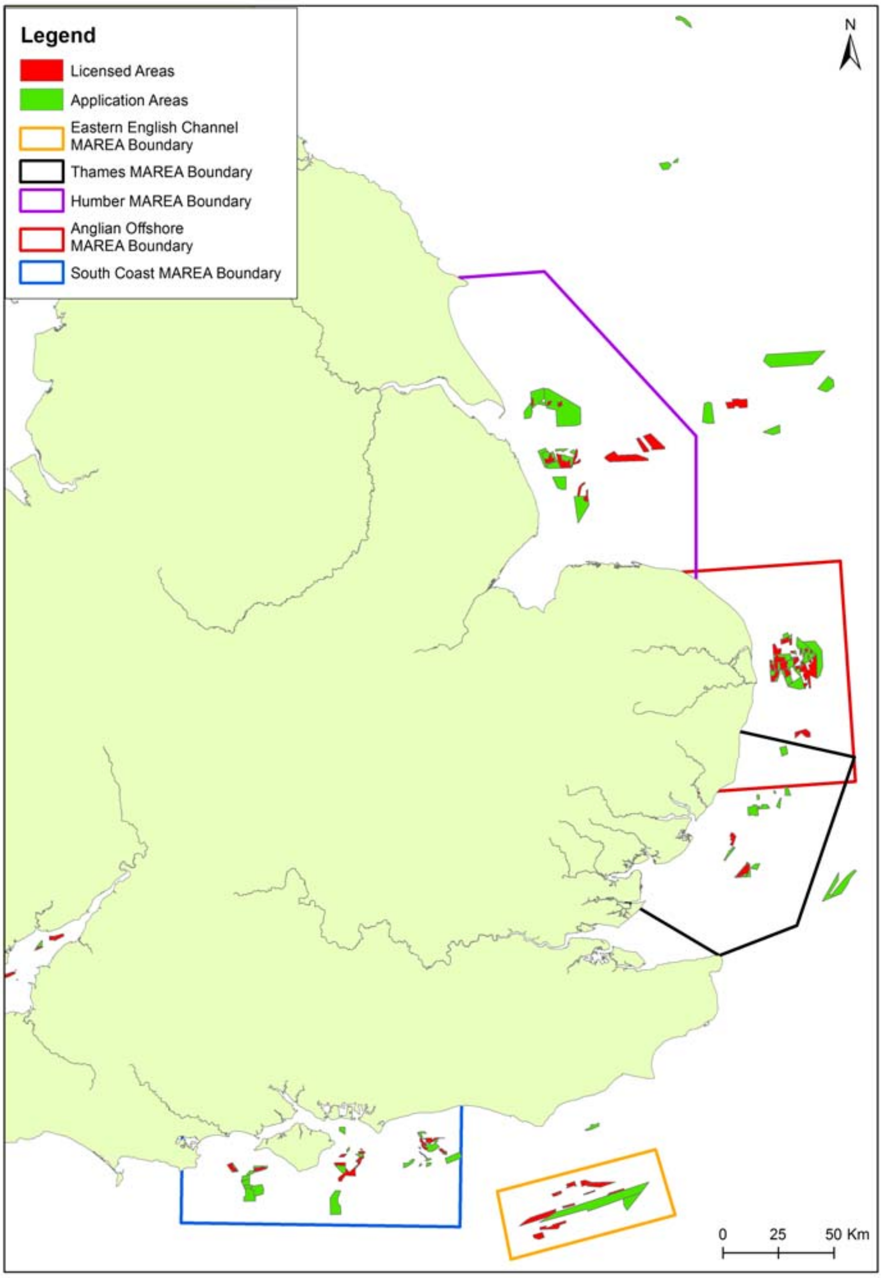
The objectives of this report are to present the considerations of environmental effects from marine aggregate extraction activities on Atlantic Herring potential spawning habitat. The analyses and assessments have considered:

- Screening all application areas for environmental effect-receptor pathways and footprints; and
- Conducting four regional Cumulative Impact Assessments (CIAs) delineated by Marine Aggregate Regional Environmental Assessment (MAREA) region boundaries.

In its simplest form the aim of this report is to screen all marine aggregate extraction application areas against spatial overlap with areas of seabed that have the potential to support Atlantic Herring spawning activity. Any application area that demonstrates a spatial overlap with the seabed area in question will be screened into requiring an assessment of the environmental effects to deliver a MWR-compliant ES.

Second to the screening exercise the aim is to determine the significance of any cumulative exposure pathways and environmental impacts on habitat or seabed area that has the potential to support Atlantic Herring spawning. This is done for all marine aggregate production licences and application areas and also with other seabed user activities that are known to have a seabed footprint or which interact with spawning Atlantic Herring. This is delivered via a regional CIA conducted at a MAREA-scale[1] (Humber, Anglian, Outer Thames Estuary and South Coast).

Figure 1.1: Marine Aggregate Regional Environmental Assessment Study boundaries, existing marine aggregate licences and application areas. (Source: The Crown Estate, 2013)



Note that the Eastern English Channel MAREA region is not included in this assessment as it already has a specific Atlantic Herring potential spawning habitat assessment and monitoring protocol in place (ECA and RPS, 2010a, 2010b, 2011).

[1] The Eastern English Channel region is not included as part of the assessments detailed in this report. The distribution of Atlantic Herring potential spawning habitat, and impact assessment, has been conducted through a separate process (ECA and RPS, 2010a, 2010b, 2011).

1.3. Cumulative effect pathways

In English territorial waters there are several seabed user industry activities that are likely to interact with Atlantic Herring potential spawning habitat e.g. dredge and benthic trawl fisheries; offshore windfarm arrays; marine aggregate extraction; dredge disposal sites; telecommunications cable routes; and oil and gas supply pipelines. These activities are considered at a MAREA-scale as part of the regional CIAs, to assess any possible damage or deterioration to the potential habitat that Atlantic Herring may use for spawning. The spatial analysis conducted has allowed levels of contribution to environmental cumulative effects from existing and proposed marine aggregate operations with other seabed user sector footprints to be determined. The rationale for the assessments within this report is to determine the worst case environmental footprint of all activities, allowing precautionary assessments to be conducted.

It is important to note that the considerations of seabed user footprints (aside from marine aggregate licence areas) presented within this report itself relate to the spatial extent of the exposure/interaction between the sector and seabed sediments and habitat that has the potential to support Atlantic Herring spawning activity. Values and quantities presented in this report do not directly relate impact assessments; they merely present a quantification of spatial area for comparison between seabed user sector footprints. Considerations of the cumulative impacts are presented in the regional CIAs.

1.4. Atlantic Herring spawning beds and the scale of the study and assessments

As mentioned in Section 1.1, the nature of Atlantic Herring spawning beds have quite specific characteristics which are still not well understood (see references cited in Section 1.1). While it is not a fault of the study or the regional CIAs, the assessment, by necessity, has used data at a macro-scale that does not allow the necessary resolution to actually identify specific discrete and individual areas of seabed with the potential to act as Atlantic Herring spawning beds. This is mainly due to the fact that Atlantic Herring spawning beds are typically small localised features. In reality actual spawning habitat, or habitat that could be used for spawning activity in the future, will likely comprise relatively small seabed features, with discrete spatial extents, although these may be spread across wide areas of suitable seabed sediment habitat at a regional-scale e.g. spawning grounds. While it will be the role of site-specific Environmental Impact Assessments (EIAs), and associated monitoring as part of the licence conditions, to determine the potential presence of such localised habitat features, this report, and the regionals CIAs, are still able to provide relevant analyses to enable a consideration of potential effect-pathways at a wider seas- and regional-scale.

It is clear from the study and the regional CIAs undertaken that in general terms marine aggregate extraction represents a relatively small contribution to the spatial interaction with areas of seabed likely to represent spawning beds or grounds, or which have the potential to be spawning grounds, in comparison with other anthropogenic activities. The distribution and extents of seabed sediments able to support Atlantic Herring spawning, and which are within the known range of spawning populations, is such that marine aggregate extraction is unlikely to significantly restrict recruitment to the adult population.

2. Rationale and methods used in the assessment

The MMO and the RAG initially advised the types of effect and effect-receptor pathways that need to be considered as part of the requirements of the EIA Directive as transposed to the MWR (MMO, 2013a). For Atlantic Herring the environmental effects and effect-receptor pathways of potential impacts are:

- Direct removal of potential spawning habitat and eggs, along with physical alteration of the structure of the sediments from direct contact with the draghead. These effect-receptor pathways relate to the primary impact zone (PIZ);
- Smothering of *in situ* eggs through deposition from the sediment plumes and sediment mobilisation, and alteration of potential spawning habitat by fining from settling sands. These effect-receptor pathways relate to the secondary impact zone (SIZ);
- With historic spawning grounds which currently have very little or no spawning activity but which can be *re-colonised* due to subsequent seabed recovery from impacts and the ability to support spawning activity over time (ICES, 2012). The area of seabed associated with *re-colonisation* potential, post-dredging, is represented by both the PIZ and the SIZ[2];
- Potential population level effect of marine aggregate dredging on Atlantic Herring are not considered to be required to be assessed under the MWR application process (MMO, 2013a)[3]; and
- Entrainment of adult Atlantic Herring and larvae by the dredger draghead are not considered significant in the context of an EIA[4].

Therefore, no consideration will be provided of the effects associated with:

- Sediment plumes on the larvae e.g. fines affecting the feeding of post-yolk sac larvae;
- Entrainment of larvae and adults; and
- Any effects resultant at an adult population-scale from receptor-effect pathways listed above and presented in the box below.

The MMO and RAG has advised that a statement should be included in all marine aggregate licence area ESs detailing that adult population level effects are not required to be assessed (MMO, 2013a).

[2] Determinations regarding the potential for *re-colonisation* regarding requirements to leave the seabed in an appropriate state at the end of the term of the licence period, will also be drawn from an application's ES.
[3] This advice is linked to the latest review by the ICES Herring Assessment Working Group (HAWG), which has assessed the North Sea populations of Atlantic Herring as presently being at sustainable levels (ICES, 2012). Recruitment of larvae and juveniles is currently a cause for concern; therefore the *foci* of the assessments presented in this report are concerned with effect pathways on habitat with the potential to support spawning activity and not adult populations (ICES, 2012).
[4] Therefore entrainment effects will not be considered in any marine aggregate area application under the MWR.

Marine aggregate licence applications in relation to an EIA of likely effects on Atlantic Herring potential spawning habitat will specifically need to consider effect-receptor pathways for:

The Primary Impact Zone:

- **Direct removal of suitable sediment;**
- **Direct removal of eggs;**
- **Alteration of habitat structure; and**
- **Recovery of suitable habitat to support future possible spawning activity (*re-colonisation*).**

The Secondary Impact Zone:

- **Smothering of eggs;**
- **Fining of suitable habitat; and**
- **Recovery of suitable habitat to support future possible spawning activity (*re-colonisation*).**

The methodology used in this report is applied in 2 stages:

Stage 1. Habitat indicator and exposure pathway mapping through the use of multiple indicator data layer overlaps and resultant 'heat' maps which allow the screening of spatial interactions for application areas (PIZs) and SIZ footprints; and

Stage 2. Regional CIA.

Stage 1 applies the adapted spatial screening methodology from Reach *et al.* (2013) and results in a screening of receptor-exposure-effect pathways between marine aggregate licence and application areas (and respective SIZs) and seabed areas with the potential to support Atlantic Herring spawning. The pathways are analysed in a Geographical Information System (GIS), and a confidence assessment of the data used is applied (Appendices C-F). These areas of seabed with the potential to contain spawning habitat are identified through the overlap of data layers that are deemed indicative of spawning habitat or events. The greater the number of overlapping data layers then the greater the 'heat' mapped and the higher the confidence that the seabed may be suitable for spawning.

Licence and application areas which have overlap (i.e. an exposure footprint exists) with receptor layers (i.e. potential spawning habitat/areas) are screened into further assessment and proceed to the Stage 2 assessment. Any licence or application areas which produce no exposure pathway are screened out at the end of Stage 1 and do not require further consideration for EIA or CIA.

Stage 2 conducts a CIA for each of the marine aggregate strategic regions (Figure 1.1) using the MAREA region boundaries and the respective MAREA impact assessment protocols and methodologies (suitably adapted as necessary to the scope of this assessment) (EMU Ltd, 2012a, 2012b; ERM Ltd, 2010, 2012; Appendices H-K). The rationale for this process allows the regional CIAs to act as supporting reports to each of the MAREAs; regarding the characterisation of Atlantic Herring potential spawning habitat and subsequent impact assessment.

2.1. Precautionary envelope

To set a suitable level of precaution within the study it is assumed for the purposes of quantifying spatial interactions between marine aggregate dredging impact pathways and areas with the potential to support spawning, that the entire extent of the application area is treated as the PIZ i.e. dredging is assumed to occur anywhere within the boundary of the licence or application area. This worst case scenario will assume the highest level of spatial interaction possible. This rationale is also applied where other seabed user footprints associated with plans or projects (yet to be licensed, constructed or deployed) are likely to interact with potential spawning habitat (see Section 2.3.1 for further detail).

The worst case scenario is considered precautionary as it over-estimates the spatial extent of Active Dredge Zones (ADZs), within any, and all, licence and application areas, and the extent of associated sediment plumes. In reality the footprint of dredging activity (ADZ) is likely to be discrete and localised (within the wider area of the licence/application area) for periods of time associated with the aggregate resource, its volume and market demand for that resource/product. Therefore, in relation to effect-receptor pathways:

- Direct removal of spawning habitat and eggs (and smothering), would only occur during a dredging event and when eggs were also present. The presence of eggs on the seabed and the presence of a dredger in the licence area are both time-limited events and may not necessarily be concurrent. Additionally, even if a whole licence area was covered with eggs, a single, or small number of, dredging events would only affect a small portion of the area; and
- It is assumed that habitat loss/conversion occurs across the totality of the licence/application area and within the associated SIZ with a transition from potentially suitable to wholly unsuitable habitat in regards to sediment composition i.e. a shift from preferred and/or marginal sediment habitat type to unsuitable sediment habitat type. In reality there are several reasons why this is unlikely to actually happen, not least the monitoring and mitigation measures required of the industry in modern licence conditions.

2.2. Revisions to the methods used in the assessment: results of further consultation with the MMO and RAG

It should be noted that following submission of a working draft report (version 0.8) to the MMO for consultation, subsequent revisions were requested to the previously agreed methodologies and the analyses, results and determinations presented in the report, by the MMO and the RAG. Through September and October 2013 a series of meetings were held between BMAPA, representatives of the EIA WG, the MMO and RAG to address the changes to the rationale for the assessments, alterations and clarifications regarding the confidence assessment methodology, data layer analyses to be used, and the subsequent presentation of results and determinations (Cefas, 2013a, 2103b; MMO, 2013b, 2013c).

The discussions held at the meetings have adjusted the rationale for the study detailed in this report and the attached regional CIAs (as agreed in the 01 May 2013 meeting; MMO, 2013a) (Cefas, 2013a, 2013b; MMO, 2013b, 2013c; Appendix L). This is reflected in the Appendix A addendum and the version 6.0 confidence assessment protocol presented in Appendix B.

2.2.1. 'Heat' mapping

The focus of the spatial (mapping) assessments is through the analyses of multiple overlaps of data layers used in the assessment methodology and the resultant 'heat'. In effect the greater the number of data layers overlaps, then the higher the 'heat' and the associated confidence that the area of seabed mapped has the potential to support Atlantic Herring spawning. Whilst the 'heat' mapping existed in the version 0.8 draft report, clarification is provided within this final report version 1.0 regarding the use of the seabed sediment classification previously referenced as preferred and marginal habitat types. These seabed sediments and their associated Folk classes are not directly indicative of spawning habitat *per se*, but are representative of the sediment types that are known to be associated with habitat used by Atlantic Herring for spawning. These sediment types are now referenced as preferred and marginal habitat sediment classes (see Section 2.3 and Addendum to Appendix A). The emphasis is now on using these habitat sediment classes as a 'base-map' (unchanged from the methodology in Appendix A) and overlaying the other data layers considered within the methodology to produce the 'heat' maps developed for each of the regions assessed.

As part of the extended consultation process the confidence assessment protocol and methodology was revised to re-classify the 'heat' mapping process and extend the 'heat' classes to ensure consideration of the full range of data layers (see Appendix B for full detail of the protocol and methodology). The previous methodology mapped 'heat' as three classes: **low** = 1-4 data layer score overlaps, **medium** = = 5-8 data layer score overlaps and **high** = 9-12 data layer score overlaps. Cefas indicated that there were additional data layer overlaps that could theoretically be possible. Therefore a fourth class of 'heat' has been categorised as **very high** = 13-16 data layer score overlaps. It should be noted that the 'very high' class cannot be mapped in this study (including any of the regional CIAs) as the required number of data layer overlaps is not achieved i.e. there is no area of seabed where all layers overlap allowing a score of 13-16. The revised methodology has been agreed with Cefas and the MMO (Cefas, 2013a, 2013b; MMO, 2013b, 2013c).

2.2.2. International Herring Larvae Survey (IHLS) data

Clarification regarding the manipulation of the International Herring Larvae Survey (IHLS) data, including interpolation of these data, has been provided within the confidence assessment protocol and methodology (see Appendix B) and is also reproduced in Section 3.4. This represents dedicated discussions between the Marine Aggregate EIA WG and Cefas specialists to ensure that sufficient information is provided regarding the manipulation of the IHLS data within the Appendix B methodology and adequate consideration is presented within this report.

2.2.3. Specific stipulations regarding data used in the report and cumulative impact assessments

As part of the consultation on the draft report, the MMO and the RAG have provided a series of specific stipulations regarding the data used in the report and cumulative impact assessments. Details of these conditions are presented in Appendix L along with a Marine Aggregate EIA WG position regarding these matters. Where appropriate the EIA WG has included the consideration of these factors on the data used as part of the analyses and subsequent determinations presented within the CIAs and this report.

Regardless of these stipulations the EIA WG has confidence in the approach adopted as it draws on multiple and different data sources and is fit-for-purpose in terms of regional scale assessments.

2.3. Stage 1 assessment methodology

The Stage 1 methodology maps and screens the spatial interactions between marine aggregate licence and application areas (PIZs) and respective SIZs (all the effect footprints) with Atlantic Herring (the receptor) potential spawning habitat data layers. This is the 'heat' mapping using the 'heat' classes of low, medium, high (and theoretically very high) as discussed in Section 2.2.1 above. The methodology uses a tiered approach to map habitat sediment classes (preferred and marginal habitat sediments), ecological space, and various data layers that demonstrate the presence of Atlantic Herring spawning events e.g. spawning data (Coull *et al.*, 1998), fisheries VMS data and IHLS data etc. These multiple data layers and the associated 'heat' of spatial overlaps indicate appropriate receptor spatial extent as identified in Reach *et al.* (2013) (Appendix A). The methodology scopes down from population distributions at a wider regional sea area level; through potential habitat sediments at a sea/basin-scale; to potential habitat sediment extent at an appropriate regional scale (as determined by the MAREA study boundaries; see Figure 1.1). These data are used to produce the broad scale potential spawning habitat characterisation map (the base-map). The base-map is then used in conjunction with existing licence area and application area boundaries (PIZ footprints), SIZ footprints and data indicative of potential spawning habitat/areas of seabed to allow licence and application area-specific screening to be conducted (see Reach *et al.*, 2013; Appendix A).

Any existing licence area or application area (or associated SIZ) that overlaps with an extent of suitable potential spawning habitat/seabed area identified at Stage 1 is screened <u>into</u> further assessment i.e. there is a receptor-effect exposure pathway.

Any existing licence area or application area without any spatial overlap identified through Stage 1 is screened <u>out of</u> further assessment i.e. there is no receptor-effect exposure pathway.

The Folk sediment classification (Folk, 1954) has been used to describe seabed habitat as this is also the classification scheme used to underpin the British Geological Survey's (BGS's) 1:250,000 scale seabed sediment maps. This sediment classification has subsequently been used within the Marine Aggregate Regional Environmental Characterisation (REC) and MAREA reports. Using the Folk (1954) classification enables compatibility of the Atlantic Herring potential spawning habitat environmental assessments with a range of products (e.g. MAREAs, marine planning areas) and data sources (e.g. BGS 1:250,000 maps).

The review and analysis of the source data for potential spawning habitat (see Reach *et al.*, 2013; Appendix A) resulted in the development of the seabed sediment classification presented in Figure 2.1. The sediment divisions, referred to as **habitat sediment classes** (using the Folk classification; see Appendix A and associated addendum), have the potential to support Atlantic Herring spawning and are presented in Tables 2.1 and 2.2.

Table 2.1: Description of Atlantic Herring potential spawning habitat sediment classes. (From Reach *et al.*, 2013; Appendix A)

Preferred habitat sediment class	In the context of this methodology these are the sediment divisions/units represented by Gravel and sandy Gravel which Atlantic Herring favourably select as part of their spawning habitat requirements. It should be noted that other physical, chemical and biotic factors contribute to the overall definition of potential spawning habitat – see also *Prime* and *Sub-prime* descriptions.
Marginal habitat sediment class	In the context of this methodology this is the sediment division/unit represented by gravelly Sand which Atlantic Herring may select as part of their spawning habitat requirements. This sediment class has adequate sediment structure but is less favourable than preferred habitat – see also *Suitable* descriptions
Unsuitable habitat sediment class	Seabed sediment classes which have inadequate sediment structure to be chosen by Atlantic Herring for spawning grounds
Prime Habitat Sediment Class	In the context of this methodology these are the sediment divisions/units represented by Gravel and sandy Gravel with ideal sediment structure that supports Atlantic Herring spawning activity – see also *preferred habitat sediment class*. It should be noted that other physical, chemical and biotic factors contribute to the overall definition of potential spawning habitat
Sub-prime Habitat Sediment Class	In the context of this methodology this is the sediment division/unit represented by gravelly Sand which has acceptable sediment structure and supports Atlantic Herring spawning activity This sediment class has adequate sediment structure but is less favourable than *prime habitat sediment*– see also *preferred habitat sediment class*
Suitable habitat sediment class	Atlantic Herring habitat sediment which has adequate sediment structure but is likely to only support low density of spawning activity. This is represented by gravelly Sand Folk sediment class – see also *marginal habitat sediment class*

Table 2.2: The partition of Atlantic Herring potential spawning habitat sediment classes. (Source: Folk, 1954; From Reach *et al.*, 2013; Appendix A)

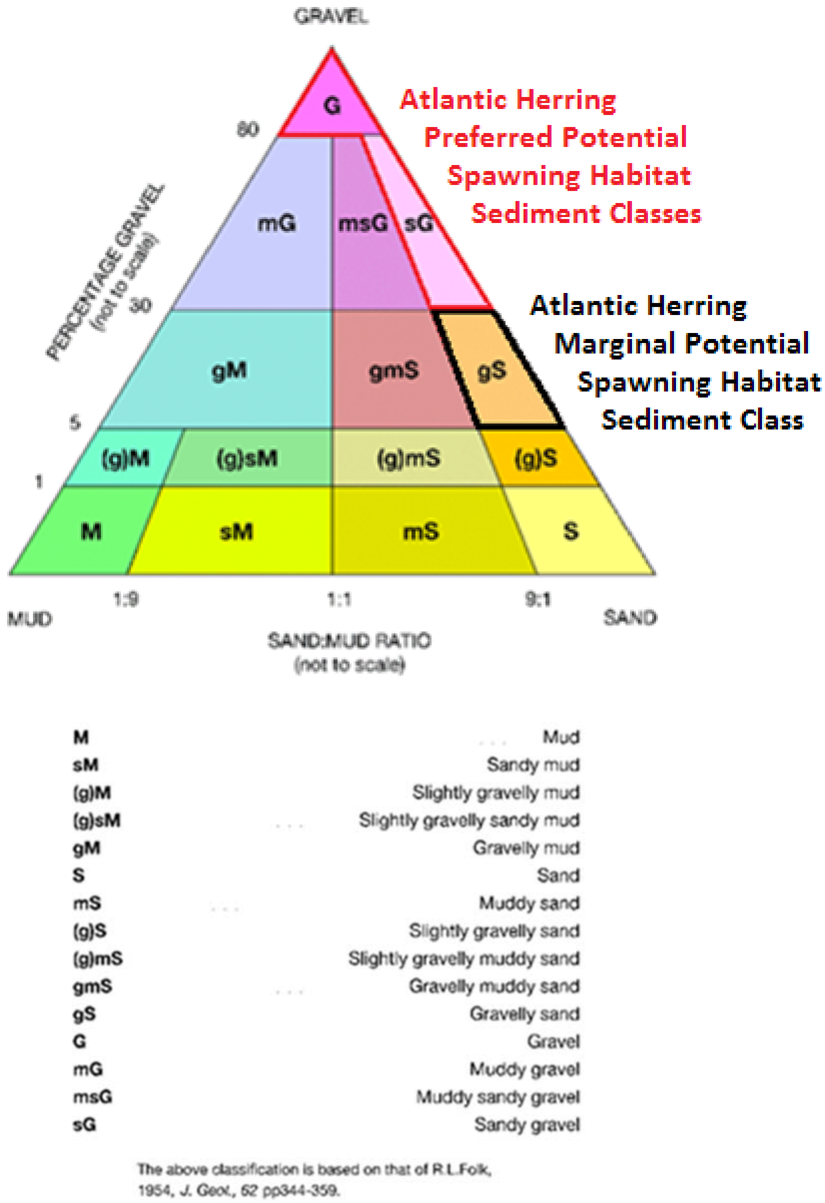
% Particle contribution (Muds = clays and silts <63 µm)	Habitat sediment preference	Folk sediment unit	Habitat sediment classification
<5% muds, >50% gravel	Prime	Gravel and part sandy Gravel	**Preferred**
<5% muds, >25% gravel	Sub-prime	Part sandy Gravel and part gravelly Sand	**Preferred**
<5% muds, >10% gravel	Suitable	Part gravelly Sand	**Marginal**
>5% muds, <10% gravel	Unsuitable	Everything excluding Gravel, part sandy Gravel and part gravelly Sand	**Unsuitable**

This habitat sediment classification, and the sediment divisions used, was ratified by the MMO and RAG at a meeting held on 01 May 2013 (MMO, 2013a). First, it is important to note that the Folk (1954) sediment classes over-represent the suitability of an individual class to completely represent sediment habitat that will be used by Atlantic Herring for spawning. This is due to the percentage of muds component within the sediment divisions. However without a complete re-working of all the BGS data used in developing the 1:250,000 scale sediment maps a direct representation of the <5% muds (<63 µm) is not possible. The MMO and RAG agreed that such an exercise is beyond the requirements of any specific EIA (as required under the MWR). Therefore the best-fit Folk sediment classification, as described in Appendix A and presented in Figure 2.1, has been used to conduct the assessments within this report.

Second, it is important to clarify that the habitat sediment classification is not the only parameter (datum) that indicates potential spawning habitat. There are other environmental (physical, chemical and biotic) parameters such as: oxygenation, siltation, overlap with range of spawning populations, micro-scale seabed morphological features e.g. ripples and ridges; which all contribute to the suitability of seabed habitat to be used as spawning beds by Atlantic Herring.

Considering the wide range of environmental parameters that determine Atlantic Herring spawning, it is important to note that the use of the habitat sediment classes alone will always over-represent the range of habitat with the potential to support Atlantic Herring spawning events. This results in the rationale for using as many indicative data layers as possible and determining representation of potential for spawning based on the ‘heat’ of the spatial overlaps (of the data used).

Figure 2.1: The Folk sediment triangle with Atlantic Herring preferred and marginal habitat sediment classes indicating potential spawning habitat. (Source: Folk, 1954; From Reach *et al.*, 2013; Appendix A)



2.4. Stage 2 assessment methodology

At Stage 2 the regional CIAs are conducted (one for each of the four MAREA regions assessed in this report: Humber, Anglian, Outer Thames Estuary, and South Coast). All existing licence areas and application areas that are screened in at the end of Stage 1 will contribute to a cumulative effect footprint. Furthermore there may be cumulative effects with other seabed user industries with the same environmental effect exposure pathways and footprints. Stage 2 maps the effect footprints of all known and foreseeable activities (plans or projects) and assesses the levels of spatial interaction with Atlantic Herring potential spawning habitat ‘heat’ maps. Through this process the level of contribution of marine aggregate extraction-specific effect footprints can be related to those from other sectors. The percentage of area of habitat overlap (percentage of contribution per activity) at a regional (MAREA) scale can be calculated. These values can be related to the potential spawning habitat extents within the MAREA region, facilitating the CIA. No inferences on the respective significance of user activities interacting with areas of seabed that may have the potential to support Atlantic Herring spawning are made within this report.

As the regional CIAs are intended to synergise with each of the MAREAs (regarding the impact assessment of Atlantic Herring potential spawning habitat) then the respective MAREA impact assessment protocols and methodologies will be used during this stage (EMU Ltd, 2012a, 2012b; ERM Ltd, 2010, 2012). This provides a consistency of approach, with this Atlantic Herring assessment building on an existing structure. However, the MAREA methodology was intended to address regional-scale issues for broad groups of receptors, so where appropriate the assessment has been adapted to provide a more effect-specific approach (Appendices H-K). Therefore the regional CIAs are not direct supplements to the existing MAREAs but are intended as synergistic assessments that address the gaps regarding Atlantic Herring spawning impacts identified within the MAREAs (MarineSpace Ltd, 2013a, 2013b, 2013c, 2013d).

2.4.1. Seabed user footprints

The seabed user footprints have been established to ensure that seabed footprints are represented as realistically as possible. Where available, exact footprints have been sourced and used. However, due to the spatial scale over which many of the footprints occur, the type of data available e.g. VMS, and considering the available information associated with some projects still in the planning stage, it has not been possible to map all the footprints in detail. Instead a standard (generic) footprint has been applied to ensure consistency. Table 2.3 outlines the seabed user sector, the footprint applied and the rationale for this.

As stated above, where available, exaction footprints have been used to generate the spatial interaction with the seabed. Where a seabed user footprint can only be established in outline (the standard footprint), a generic approach to establishing a realistic worst case detailed footprint has been adopted to ensure that the full spatial footprint of interaction with the relevant habitat can be established. Therefore, where a standard footprint has been used, the worst case interaction with the relevant habitat has been established i.e. the footprint has been mapped to interact with the greatest extent of the relevant habitat, rather than an interaction with a minimal area.

The results of the seabed user sector footprint analyses present a spatial analysis of the data only (see Section 4). No inferences on the respective significance of user activities interacting with areas of seabed that may have the potential to support Atlantic Herring spawning are made within this report.

Table 2.3: Seabed User Spatial Footprint Parameters

Seabed User	Generic Footprint	Parameter Rationale	Data source
Pipelines	700mm diameter	Pipelines do vary in diameter depending upon their purpose. An average representation of this range of pipeline diameter is used, which will also account for any protection required.	Crown Estate
Power Cables Proposed Power Cables	300mm diameter	Power cables vary in their diameter depending up on their role (export, interconnection, distribution etc.). An average diameter of 300mm was used to take into account the cable footprint and any protection or movement that might be required.	Oceanwise
Telecommunication Cables	50mm diameter	Standard practice for telecommunications cable within shallow seas is to armour them, resulting in a diameter of 50mm.	Oceanwise
Disposal Sites	As stipulated by Cefas		Cefas
Commercial Fisheries Only those fishing gear types that directly interact with the seabed were used.			
Demersal Trawling	Footprint of 5 years of VMS data (2007-2011)	5 years of VMS data was utilised and where activity occurred within the VMS 1.8nm x 3nm rectangle it was included as part of the footprint. This therefore locates where this type of activity is most likely to occur.	MMO
Dredging Gear	Footprint of 5 years of VMS data (2007-2011)		MMO
Offshore Windfarms (OWF)			
Operating OWF	50m diameter	Where the turbine footprint is known a standard footprint diameter has been applied to each turbine location. The average footprint takes account of turbine foundation and anti-scour footprint and variations in foundation design.	Crown Estate And Oceanwise
OWF under Construction	50m diameter		

Seabed User	Generic Footprint	Parameter Rationale	Data source
Proposed OWF	75m diameter	Where the OWF site boundary is known, but no turbine footprint has been confirmed as of June 2013, and standard turbine grid has been applied. The grid dimensions are 1,155m x 1,617m. The applied grid and the greater foundation diameter take into account that the majority of these sites are Round 3 (or extensions to existing sites) and will therefore be further offshore and in deeper water. Therefore, larger turbines with greater blade sweep are expected to be deployed, resulting in increased distances between turbines (in comparison with Round 1 and 2 arrays, and with larger foundation footprints and any associate anti-scour protection.	
Aggregate Extraction Areas			
Current Licence Area	Licence boundary	The boundary co-ordinates were downloaded from the Crown Estate website in June 2013. They represent the entire footprint over which aggregate extraction could occur.	Crown Estate
Application Area	Application boundary		
Option Area	Option boundary		

2.5. Confidence assessment methodology

Confidence in the mapped Atlantic Herring potential spawning areas is required for all the exposure pathways (PIZ and SIZ). Any confidence assessment that is informed through multiple data layers needs to:

- Assess the confidence in each data layer; and
- Determine the combined confidence in multiple layers.

Individual layers may have either spatially uniform or variable confidence, depending on the underlying data. All data are assessed to ensure a robust exposure pathway screening exercise and subsequent environmental assessment has been conducted as part of this study.

An overview of the confidence assessment process is presented here; however the detailed Confidence Assessment Protocol is presented in Appendix B and informs a thorough understanding of the rationale and methods used within this study. The rationale and methodology used in Confidence Assessment Protocol version 6.0 (Appendix B) have been discussed with the MMO, RGA and specifically Cefas and are agreed (Cefas, 2013a, 2103b; MMO, 2013a, 2013b, 2013c).

2.5.1. Data considered

The spatial datasets considered in the confidence assessment to inform the location of Atlantic Herring potential spawning grounds included:

- Seabed sediment Folk classification: BGS;
- Seabed sediment Folk classification: MAREA;
- Seabed sediment Folk classification: RECs;
- Fishing Fleet: VMS;
- Fishing Fleet: MMO sightings;
- Fishing Fleet: Inshore Fisheries and Conservation Authorities (IFCA) sightings;
- Fishing Grounds: Eastern Sea Fisheries Joint Committee (ESFJC);
- Spawning Grounds: Coull *et al.* (1998); and
- Spawning Grounds: International Herring Larvae Surveys (IHLS)

All data-sets were required in a polygon format (area of spatial extent), as opposed to point, line or raster/gridded data, as this allows them to be combined and result in an overall assessment.

2.5.2. Data omitted

The MMO fishing fleet sighting records required interpolation to create data polygons for the areas surveyed. This dataset was omitted from the study after plotting the relevant gear types against VMS (see Appendix B for full details), as the comparison indicated that the VMS data already showed the relevant gear type in the same locations presented by the MMO sightings, except for a very few cases that were not considered significant. Therefore use of the MMO fishing fleet sighting data would result in duplication of data.

The Inshore Fisheries and Conservation Authority (IFCA) dataset has also been excluded, as the full coverage dataset (representative of all IFCAs) was not supplied within the required timescales for this study. Where possible these data should be sourced for consideration within any licence-specific EIA. The MMO are currently facilitating the provision of these data to the marine aggregate sector.

The REC seabed sediment layer has been excluded because the BGS 1:250,000 scale seabed sediments version 3 dataset (BGS SBS version 3 dataset) (which is used in the confidence assessment) has been confirmed by BGS to include REC data from the Humber, Anglian and South Coast studies, but not for the Outer Thames region.

2.5.3. Confidence test method

2.5.3.1. Confidence in the data

Following review of various approaches used to date, including MESH , UKSeaMap , the MMO's approach, a scoring proforma has been developed to apply to confidence assessments as shown below (Table 2.4). This was adopted where there were no supporting spatial data to inform spatial variation in confidence.

The first five parameters (method, vintage, positioning, coverage, quality standards) are concerned with the data, i.e. how confident is the Marine Aggregate EIA WG in the data being as described, whether this is seabed sediment, spawning grounds or fishing activity?

Note that 'coverage' does not, specifically, assess spatial coverage but instead the extent of the data. If an overall reduced score was given to a dataset because it did not spatially cover the entire project area, this would reduce the score of this parameter in areas where it does indicate spawning grounds, which is not relevant. The study is interested in the data where it is provided. If it is not provided at a location, a result of zero feeds into the overall combined confidence.

Table 2.4: Data parameters and weighting used in the Confidence Assessment Protocol and Methodology.

Confidence Test	Considerations	Weighting
Method	Technique to gather, process and interpret the data, robustness and reliability, best practice, publication	1
Vintage	Age of data and suitability of age to intended use	1
Positioning	Accuracy of locations provided	1
Coverage	Coverage of the data in terms of what is included, density of points, gaps in data. Note this does not assess spatial coverage*	1
Quality Standards	Quality control information provided, review internally, externally	1
Indicator of Spawning	Suitability of the dataset to inform spawning potential	5

2.5.3.3. Confidence in the data indicating spawning grounds

The final parameter, 'indicator of spawning', is not concerned with the data themselves, but the confidence in the data indicating spawning grounds i.e. when there are no direct data on spawning measurements (such as seabed sediments), what confidence is there that the data may inform or indicate spawning grounds? As this project is using the data to assess the likelihood or confidence of spawning ground locations, this indicator parameter is fundamental to the outcome and, therefore, is heavily weighted. A weighting of 5 has been assigned during development of this methodology, and given the expert opinion of the Marine Aggregate EIA WG. A value of 5 results in this parameter holding the same weight as all the preceding 5 parameters combined.

2.5.3.4. Spatial variation in confidence

All datasets were assessed in order to consider whether any supplied parameters could be used to inform spatial variation in the confidence; whether applied to confidence in the data themselves or confidence in the indication of spawning grounds. This was only concerned with parameters that reduced certainty about the data so, for example, variation in abundance (as in the case of IHLS) or fishing time (VMS) does not reduce certainty in the data. With abundance, either there is spawning or there is not (presence/absence). This approach was approved by Cefas regarding the IHLS dataset (Cefas, 2013a, 2013b).

It was concluded that only two datasets had spatial variations in a parameter that informs confidence: seabed sediment Folk class for each of the BGS and MAREA datasets.

2.5.4. Scoring

For each parameter or confidence test shown, a score between 0 and 3 is assigned, where 0 = unknown and 3 = high confidence (Table 2.5). However for the 'indicator of spawning' (final parameter in Table 2.4), a score of 0 would mean it is unknown whether the dataset can be used to infer spawning locations. This is not applicable for this parameter; as if this were the case the layer should not be included in the project. Therefore a score of 0 for 'indicator of spawning' = very low confidence.

Table 2.5: Confidence scores used in the Confidence Assessment Protocol and Methodology.

Score	Score category
0	Unknown / none*
1	Low
2	Medium
3	High

* For the parameter 'indicator of spawning', a score of 0 = very low confidence (see above for the rationale)

The final confidence for an individual layer is calculated by adding the weighted scores, then normalising to a range of 0 to 5 (see Appendix B).

2.5.5. Confidence in the seabed habitat sediments data indicating potential spawning habitat

As detailed in Reach *et al.* (2013), Atlantic Herring is known to prefer Gravel and sandy Gravel seabed sediments; and also have a marginal habitat sediment class of gravelly Sand. Therefore the Folk sediment classification provides a spatially variable indicator to spawning and hence the level of confidence is also variable (see Section 2.3; Appendix A).

The level of confidence in Folk classes indicating potential spawning grounds needs to consider two variables. First, it needs to consider the confidence that the Folk category contains the correct sediment class, e.g. there is more confidence in Gravel indicating Atlantic Herring potential spawning habitat (hence the 'preferred habitat sediment') than gravelly Sand (the 'marginal' habitat sediment) (Appendix A; Reach *et al.*, 2013). This field is termed 'Folk category indicates marginal/preferred habitat' and is represented by the Y-axis in the matrix below.

Second, the scoring needs to consider whether the Folk class boundaries, i.e. the upper and lower limits of each of gravel, sand and mud, are representative of the potential spawning habitat, or not, e.g. the Folk category Gravel contains sediment types outside of the preferred range for Atlantic Herring spawning habitat i.e. there is the possibility that the Folk Gravel class may contain >5% muds, in which case this is unfavourable to support Atlantic Herring spawning activity. This is shown on the X-axis in the matrix below and termed 'Folk category over represents/correctly represents'.

Normally, such matrices are provided for parameters scored from low to high, or numerically, 1 to 3. However in this case, it is never possible that the BGS data can indicate spawning grounds with high confidence as it is only an indicator, i.e. direct measurements of spawning carry much greater confidence, such as IHLS. Therefore the matrix is scored from 0 to 2. As detailed in Section 2.3.4 above, where scoring the indicator for spawning, a zero score does not imply 'unknown', but 'very low' instead.

Each of the two parameters is scored separately from 0 to 2 (very low to medium); then the two are combined as shown in the matrix.

Generic Matrix	Folk category over represents = 0 (very low)	Folk category represents correctly = 2 (medium)
Folk category indicates marginal habitat sediment = 0 (very low)	0 (very low)	1 (low)
Folk category indicates preferred habitat sediment = 2 (medium)	1 (low)	2 (medium)

As per the method statement for Atlantic Herring, of the three Folk categories that represent potential spawning habitat sediment class (Gravel (G), sandy Gravel (sG) and gravelly Sand (gS)), all of these over-represent the habitat divisions. This reduces the confidence. Therefore the matrix results are as follows:

Atlantic Herring	Folk category over represents = 0 (very low)	Folk category represents correctly = 2 (medium)
Folk category indicates marginal habitat sediment = 0 (very low)	gS = 0 (very low)	N/A
Folk category indicates preferred habitat sediment = 2 (medium)	G, sG = 1 (low)	N/A

The habitat can only have a very low or low assessment due to the Folk classification limitations. If an exposure pathway exists, then the detail of the extent of preferred habitat sediment in relation to marginal habitat sediment presence and magnitude of effects will then be considered within the application's EIA.

2.5.6. Confidence in the International Herring Larvae Survey data indicating potential spawning habitat

The IHLS has the highest confidence (score of 3) as it is a direct indicator of presence/absence of 0-ringer larvae at the surface of the spawning habitat i.e. where the 0-ringer larvae are caught indicates that spawning has occurred at that seabed location; it is a direct measure of spawning. For the larvae in the central and southern North Sea the 0-ringer size range is 0-10 mm length and for the east English Channel and south coast the size range is 0-11 mm (ECA and RPS, 2011; ICES, 2012; Reach *et al.*, 2013).

Number count cannot be used to inform spatial variation in the confidence. To align with the assessment of the other data layers, the confidence is related to the standard/credibility of the data, not the scale of spawning. Therefore 0 = absence and ≥1 = present. However the Marine Aggregate EIA WG is keen that these count data should not be lost in the assessment process, i.e. number count should still be used to inform any EIA. The supporting IHLS interpolation exercise and GIS data layer will facilitate this data review and inclusion within any EIA (see Section 3.4 and Figure 3.7; also Section 5 and Figure 5.1).

The IHLS data represent direct measurements of Atlantic Herring larvae of the appropriate size classes, there is no inference, it is direct data on spawning grounds, and accordingly has the highest confidence possible. It is important to note that the IHLS data used in this study is drawn from the period 2002-2011 and only reflects the spatial coverage available from these data; with supplementary survey coverage from the Triton Knoll offshore windfarm Herring larvae survey data (RPS, 2011). Figure 3.1a and 3.1b show the known extent and location of the Banks and Downs Atlantic Herring spawning populations derived from IHLS data and includes areas of null data. Figure 3.2 shows the spatial extent of the IHLS areas. Together these spatial areas set the context for the appropriate larvae survey effort and expected distribution and extent of the known Atlantic Herring populations in the central and southern North Sea and English Channel, using these data.

There is limited survey effort south of Spurn Point into the majority of the Humber region and across the 'inshore' area of the Anglian region. It is therefore considered that whilst these areas may be of limited favourability to spawning Atlantic Herring, this is not definitive considering that the IHLS coverage does not extend across these areas of seabed i.e. there are data voids that are an artefact of poor survey coverage (ICES, 2012). Given the incomplete survey coverage of the IHLS in relation to the known extent of the spawning populations (especially the Banks population) then determinations of larvae are constrained to the spatial coverage of the IHLS (see Appendix L for further considerations and constraints). This said the IHSL data are an important data series and relevant determinations regarding seabed suitability for spawning can be drawn where these data exist.

2.5.7. Confidence in the combined data

Table 2.6 below shows the results of each of the confidence assessments per layer plus the final single layer confidence score.

These 'final single layer' confidence scores represent the value (or weight of evidence) that each dataset has as an 'indicator of Atlantic Herring spawning', taking both the quality of the data into account as well as their suitability to be used to indicate locations of Atlantic Herring spawning (see Appendix B for detail)

Each individual layer is first scored on five parameters or tests relating to the data themselves: each of these tests result in a score of 0 to 3 (Section 2.5.4, Table 2.5 and also Appendix B). These scores are then summed for each individual layer and then normalised back to a range of 0 to 3 (i.e. by dividing by the total possible score, 15, and multiplying by the range, 3). This is the total normalised value, and is provided for reference only to show how the datasets differ, irrespective of their ability to indicate potential habitat.

A single score is provided next for the confidence in the layer indicating potential spawning habitat for Atlantic Herring. This test results in a score of 0 to 3.

The total weighted score then combines all the parameter scores together. The parameter scores for confidence in the data are added to the weighted indicator score which is weighted through multiplication by 5. By multiplying by 5, the indicator score has equal weight to all the other 5 scores combined. The total weighted score for a given layer can therefore range from 0 to 30 (i.e. 5 parameter scores up to a maximum each of 3 = (5 * 3) = 15; plus one score up to 3 and multiplied by 5 = 15: giving a total of 30).

The Total Normalised Atlantic Herring score is then calculated by normalising the total weighted score for Atlantic Herring to a range of 0 to 5(i.e. by dividing by the total possible score of 30 and multiplying by the range, 5). Whilst these values could have ranged 0 to 3 as with the rest of the scores, this did not allow enough variation between the datasets. A range of 5 was considered to show a suitable level of variation (very low = 1, low = 2, medium = 3, high = 4 and very high = 5). These individual data layer values, presented as ‘Total Normalised’ in red text in Table 2.5, were assigned to each shapefile attribute table ready to contribute towards the final combined confidence mapping layers (see Section 3).

In all scores within the confidence assessment, a low number reflects low confidence in the data indicating spawning, whereas a high number reflects high confidence. For the combined data layer maps the ‘hotter’ or more intense the colour then the higher the probability that the associated seabed has the potential to support Atlantic Herring spawning. These are the ‘heat’ maps presented in Section 3.5 (and Appendices C-G) and used within the regional CIAs (Appendices H-K).

Table 2.6: Final Confidence Assessment per Individual Layer (see Appendix B)

Confidence test	Method	Vintage	Positioning	Coverage	Quality Standards	Dataset Scoring Source	Total Normalised	Indicator of Herring Spawning	Total Weighted Score	Total Normalised
Range from 0 to >>	3	3	3	3	3		3	3	30	5
Weight	1	1	1	1	1			5		
IHLS	3	3	3	3	3	EMU	3	3	30	5
MAREA Preferred	2	3	3	3	2	MESL	3	1	18	3
ESFJC	2	2	1	1	0	EMU	1	2	16	3
Coull et al	1	1	1	2	0	MESL	1	2	15	3
BGS Preferred	2	1	3	3	2	MESL	2	1	16	3
VMS	3	3	3	2	3	EMU	3	0	14	2
MAREA Marginal	2	3	3	3	2	MESL	3	0	13	2
BGS Marginal	2	1	3	3	2	MESL	2	0	11	2
IFCA Sightings	2	3	1	1	1	EMU	2	0	8	1

The combined confidence ('heat maps', see Section 3.5) is the sum of all layers at any one location. This has been produced by simply adding the score for each layer to a total: therefore, the greater the number of over-lapping data layers, the higher the probability that the seabed location represents potential spawning habitat.

2.5.8. Data layers included in combined confidence

As noted above, the IFCA sightings data were not used in the combined confidence. Therefore the total score at any location was the sum of IHLS (Atlantic Herring only), the sediment type used (whether BGS/MAREA and preferred/marginal), ESFJC, Coull *et al.* and VMS. These total scores have been plotted both numerically, as well as a simplified categorisation into **low**, **medium**, **high** and **very high**. A justification for the categories chosen is given in the following section.

It should be noted that it was not possible to combine both the BGS and MAREA seabed sediment as indicators to spawning/habitat grounds and it is advised that the best seabed sediment data are used at any individual licence area, as appropriate (MAREA data used as base-map for the Humber and Anglian regions; and BGS data used as the base-map for the Outer Thames Estuary and South Coast regions). To facilitate the use of either the BGS or the MAREA data, the combined confidence probability has been calculated separately, using both BGS and MAREA datasets as separate base-maps. Therefore, two combined confidence assessments are available for each receptor species in each of the MAREA study areas: Atlantic Herring with BGS data; Atlantic Herring with MAREA data; sandeel with BGS data; and sandeel with MAREA data.

A temporal range is associated with the data layers, with some data representing concurrent use of the seabed by, or representation of the presence of Atlantic Herring or sandeel, within the same period of time e.g. VMS data from 2010 is concurrent with the 2010 IHLS data. Where this temporal and spatial overlap occurs then a higher certainty that the data are indicating potential spawning habitat can be deduced. This is not to say that there is a lack of confidence where there is a spatial overlap of data layers but these are outside of a shared temporal overlap. These cases may result from data gaps e.g. Coull *et al.* used data up to 1998 but the IHLS dataset is from 2002-2011. In this example the lack of temporal overlap has not been penalised, as both datasets are valid in indicating the potential for that area of seabed to support spawning, with a level of certainty that this may have been the case at 1998 and between 2002 and 2011. The screening process assumes an additive nature both for space and time as part of the precautionary assessment process in determining the extent of seabed with the potential to support spawning activity.

2.5.9. Range of data presented

If all layers were to coexist at one location, the maximum possible score would be where MAREA preferred sediment is used (higher score than MAREA marginal sediments and BGS preferred/marginal sediments) and for Atlantic Herring, as this would use one extra dataset (IHLS) than available for sandeel (as considered in MarineSpace Ltd, 2013e). Therefore, the total possible score is:

5 (IHLS) + 3 (MAREA pref.) + 3 (ESFJC) + 3 (Coull *et al.*) + 2 (VMS) = 16.

This maximum score is termed the '**maximum possible data layers score**'. This is the greatest score achievable considering the associated confidence associated with any one data layer. Theoretically, a higher maximum combined score could be achievable if all data layers had the maximum score of 5 associated with each of them. As detailed in Section 2, this is however not the case so the '**maximum possible data layers score**' is the 'real' maximum score that can be achieved using the data layers available to the assessment (regional cumulative impact assessments).

What is shown by the total confidence score associated with the '**maximum possible data layers score**' is the 'weight of evidence to indicate spawning grounds/habitat' or 'quantity of overlap in layers to indicate spawning grounds/habitat', i.e. the more layers present that indicate spawning grounds/habitat, the higher the confidence; providing that all layers cover all licence regions. The scoring provides an assessment-specific (using the data available at the time of the assessment) one-off national presentation of data, showing the range of data and theoretically possible overlaps, indicating the potential that an area of seabed has the potential to support Atlantic Herring spawning.

Therefore a top range of 16 (the maximum number of layer scores that could theoretically overlap) was used in the analyses. The actual results only extend up to 12 as the data layers required for the maximum possible data layers score do not concurrently occur at any one location i.e. they are spatially restricted in such a way that they are unable to all overlap in anyone space within the study areas considered. However, in the future, additional data coverage may result in an increased spatial overlap of data layers that could increase from 12 up to 16).

2.5.10. Categorisation of data layer overlap – 'heat'

Two different methods to categorise the 'heat' of layer-overlap were considered: 'equal interval' and 'quantile' ArcGIS methods. The quantile method was rejected as it is not useful to emphasise areas of equal data coverage. Also this method does not allow use of the total maximum possible score i.e. from 13 up to 16 layers overlapping.

Therefore intervals of 4 overlapping data layers were chosen to develop the categorisation of 'heat' associated with mapping i.e. 1-4, 5-8, 9-12, 13-16. This ensures that any location with a single layer score of 5 (i.e. IHLS), is not included within the lowest category.

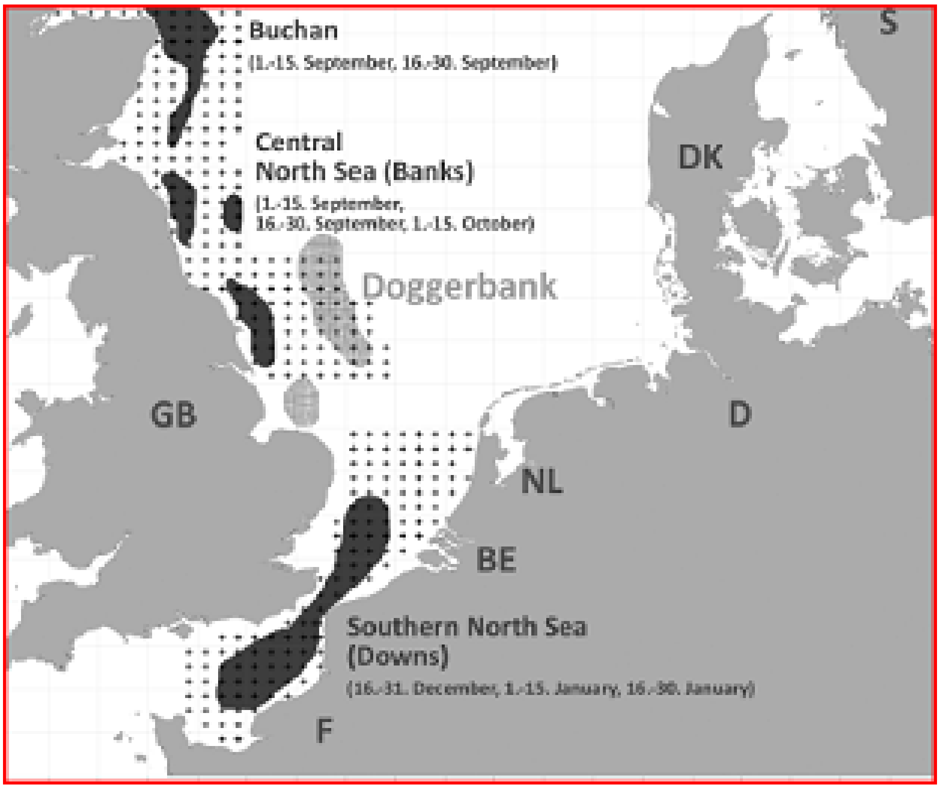
3. Results

3.1. Introduction to results

The spatial distribution of receptor indicator footprints and PIZ and SIZ data allow exposure pathways to be analysed in a GIS. Concurrently, a confidence assessment of both individual data layers and the combined exposure layers is made. Licence and application areas which have an overlap (i.e. where an exposure footprint exists) with receptor layers (potential spawning habitat/areas) are screened into further assessment and proceed to the Stage 2 assessment.

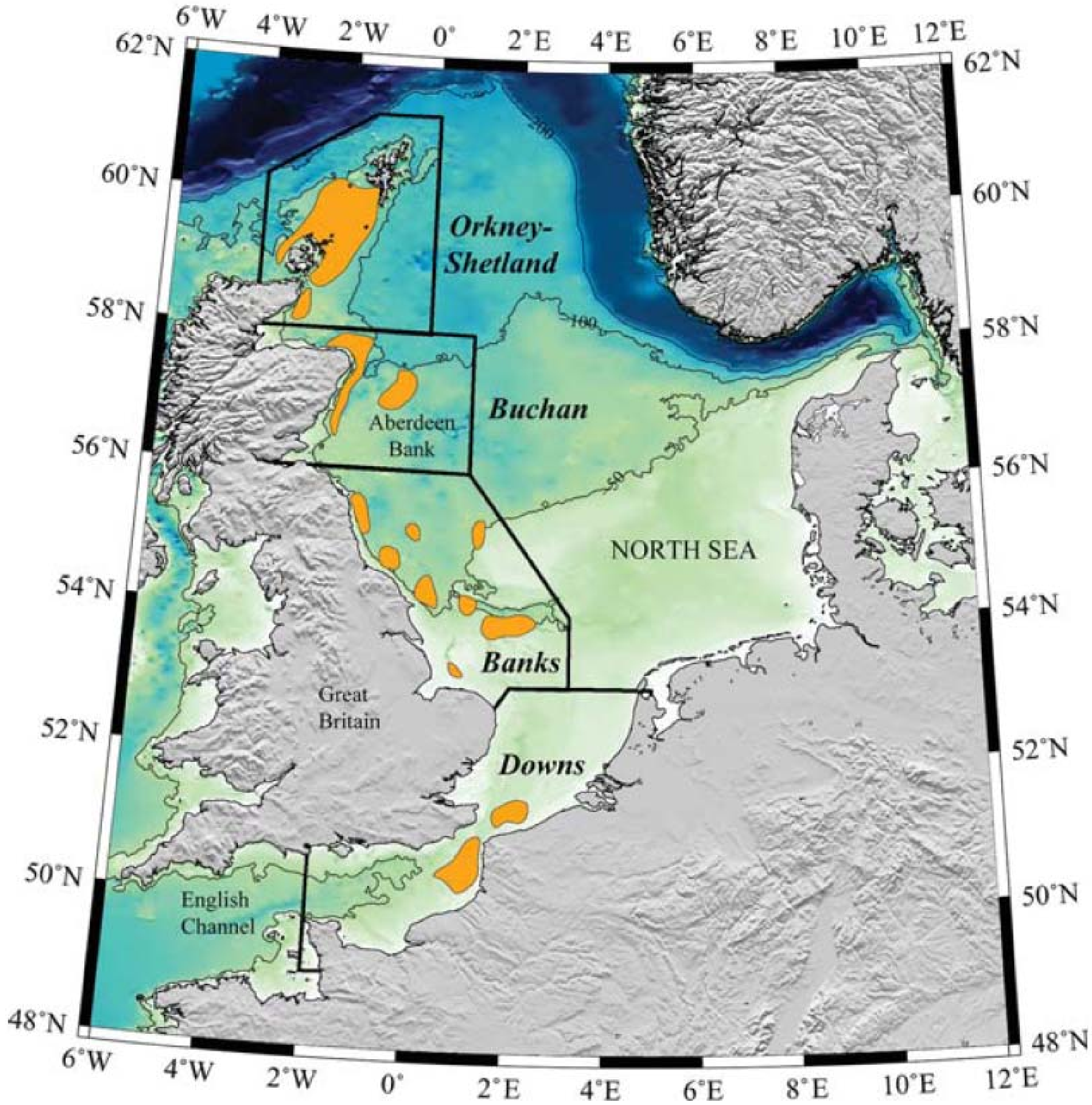
The MAREA scale assessments can also put into the context of a wider regional sea area; which is defined as the area considered to be relevant to this assessment for Atlantic Herring as previously determined in Reach *et al.* (2013) through consultation with the RAG and MMO (MMO, 2013). The wider regional sea area ranges from the Firth of Forth south, to an area just west of the Isle of Wight and out to the boundary of UK territorial waters (Figure 3.3). Seabed sediment data have been sourced from the BGS to cover this area. These data can be used to characterise the footprint of marine aggregate extraction, in relation to the total habitat within the southern North Sea and eastern English Channel, which is representative of the Banks and Downs Atlantic Herring population ranges (Figure 3.1a and b, and 3.2). The Orkney/Shetland and Buchan populations were screened out (from requiring assessment) by Reach *et al.* (2013), as the ranges are too far north to interact with any marine aggregate licence or application areas.

Figure 3.1a: Distribution of Atlantic Herring spawning populations recorded in UK Waters. (From: Schmidt et al., 2009)



NB: Black points denote IHLS stations. Stations outside of shaded areas equal null data points i.e. no larvae sampled.

Figure 3.1b: Distribution of Atlantic Herring spawning populations recorded in UK Waters. (From: Payne, 2010)



The initial data layer mapped is the representation of seabed sediment Folk classes for the wider regional sea area, showing Atlantic Herring preferred and marginal habitat sediments with the potential to support spawning activity (refer to Section 2.3 and Reach *et al.* (2013); see Appendix A for rationale for determining preferred and marginal habitat sediment classes) (Figures 3.4 and 3.5). These data have been sourced from the BGS and are represented by the BGS 1:250,000 scale seabed sediments version 3 data as delineated in Figure 3.3 (BGS SBS v3 data).

As these data also map seabed sediments outside of the MAREA regions, these data will facilitate the assessment of any marine aggregate application areas that are located outside of the MAREA region boundaries. These 'outlier' licence and application areas have undergone the Stage 1 screening exercise but have not been assessed as part of the Stage 2 assessment exercise presented in this report; as this has only been conducted for the licence and application areas within the MAREA regions.

Figure 3.2: Areas of the International Herring Larvae Survey: Orkney/Shetland, Buchan, Central North Sea and Southern North Sea. (From: The Herring Network, 2006)

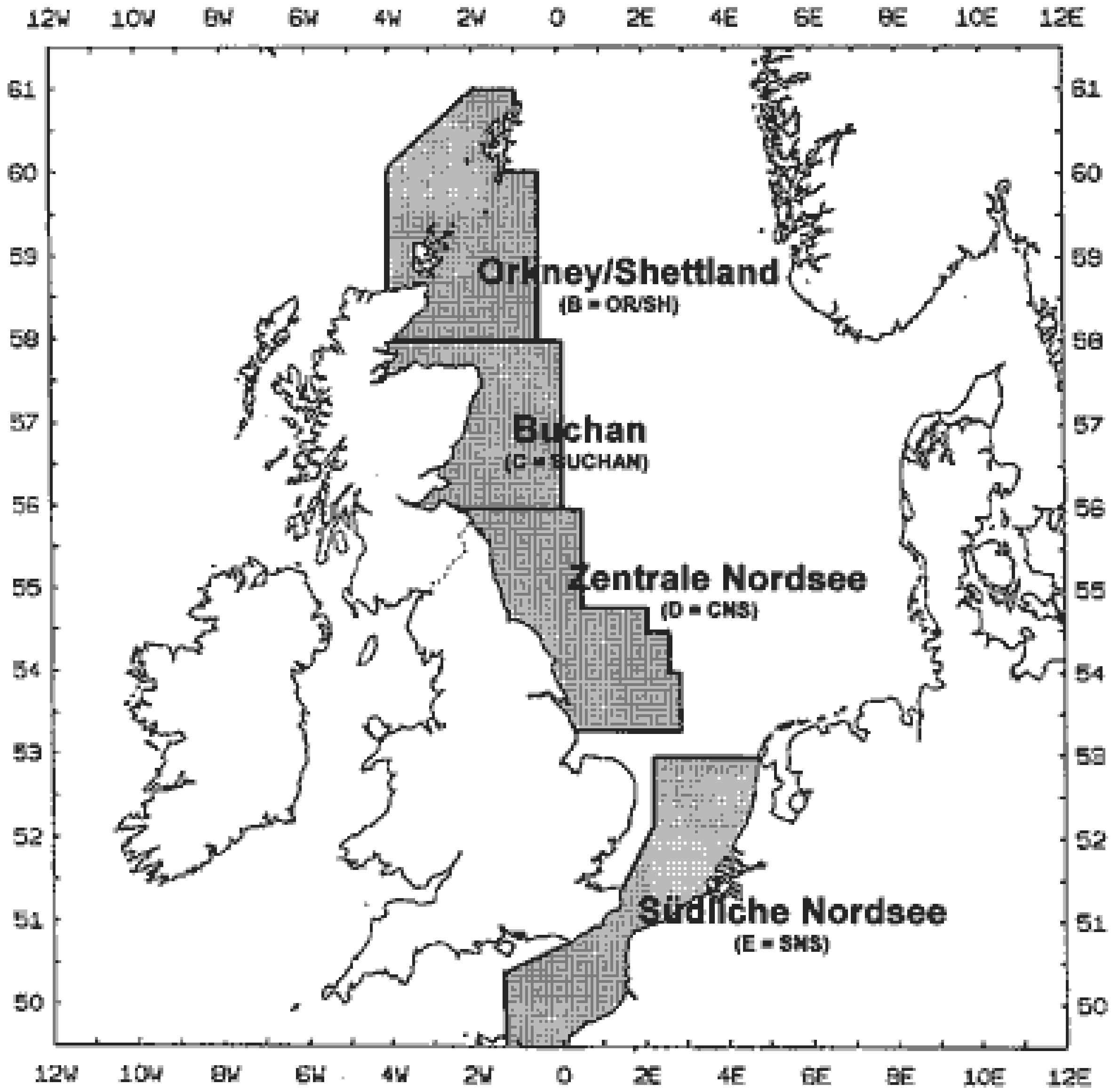


Figure 3.3: The wider regional sea area considered relevant to this assessment for Atlantic Herring

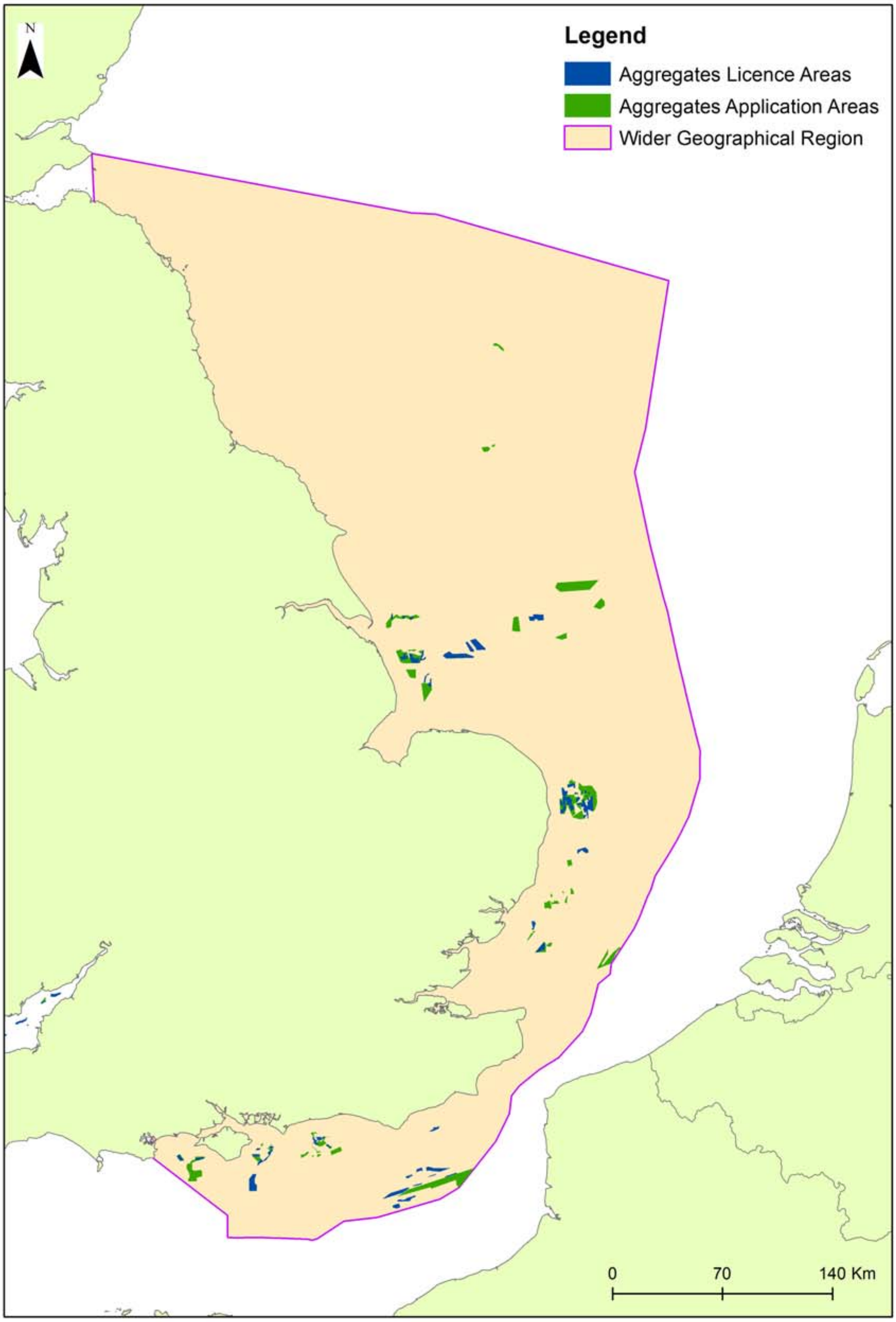


Figure 3.4: Distribution of Atlantic Herring preferred habitat sediment with the potential to support spawning. (Derived from 1:250,000 scale BGS Digital Data under Licence 2013/063 British Geological Survey. ©NERC.)

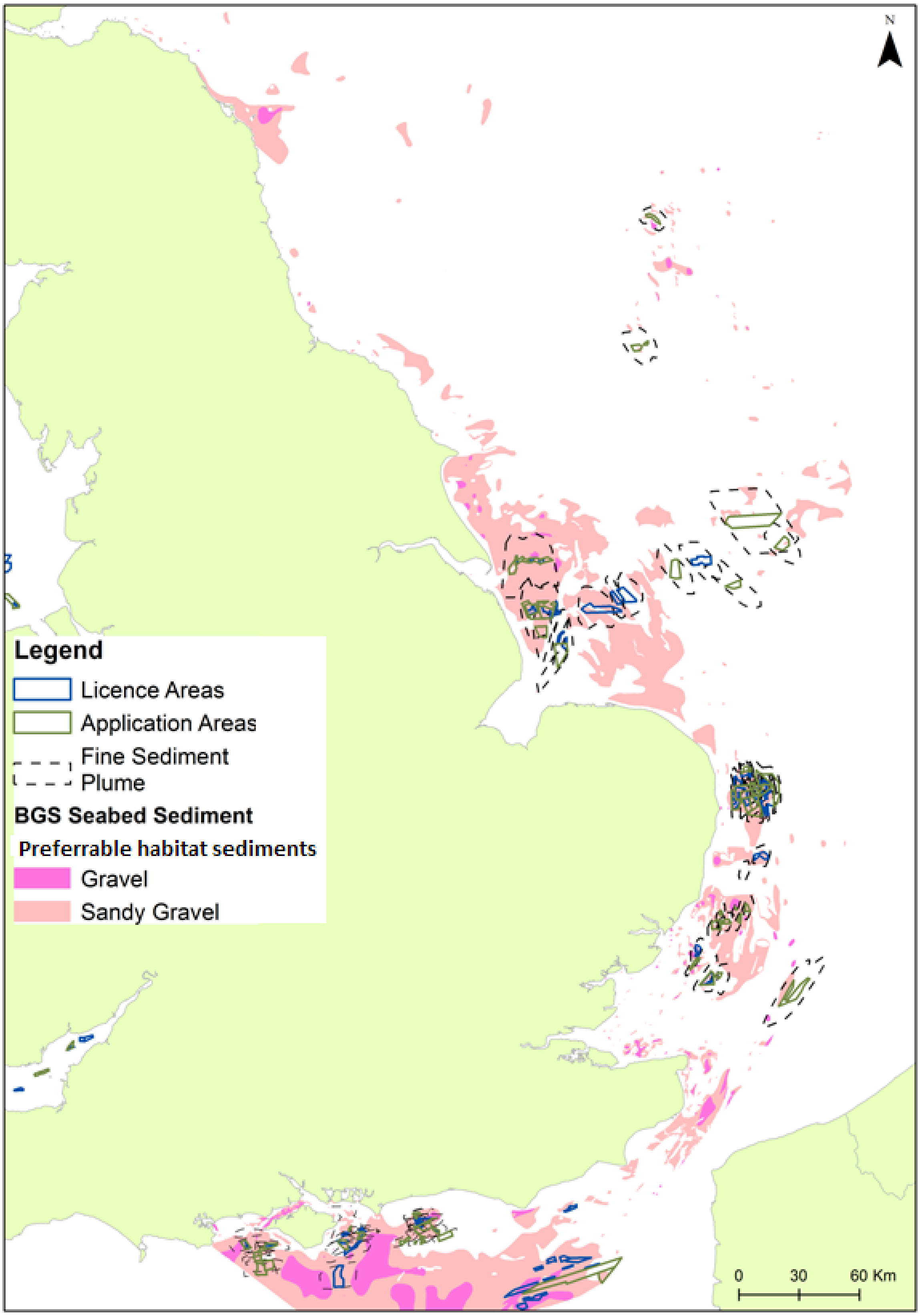
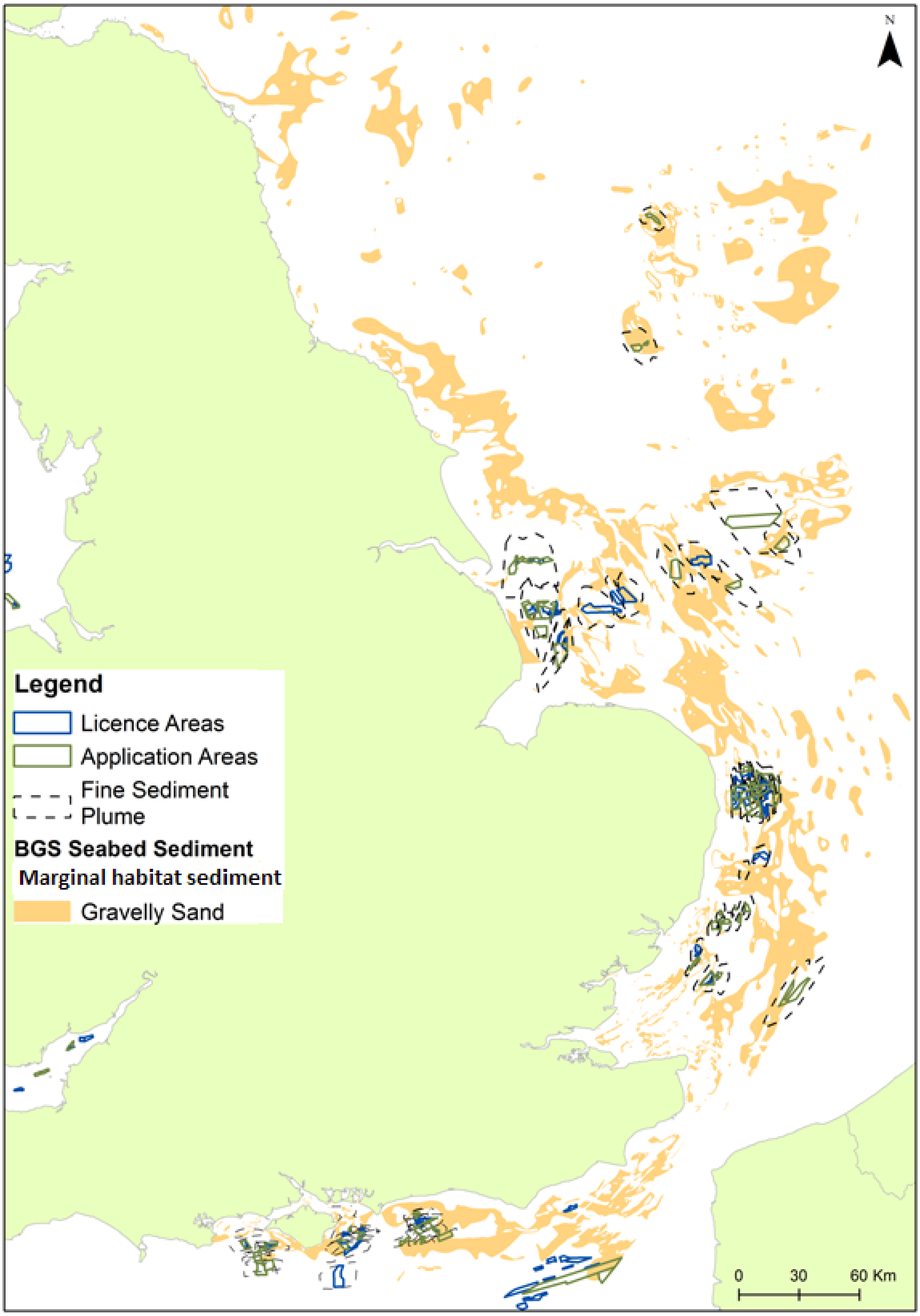


Figure 3.5: Distribution of Atlantic Herring marginal habitat sediment with the potential to support spawning. (Derived from 1:250,000 scale BGS Digital Data under Licence 2013/063 British Geological Survey. ©NERC.)



3.2. Seabed sediment maps

The seabed habitat sediment maps at a wider seas and regional scale were generated to underpin the multiple data layer 'heat' maps. A level of analysis was conducted on the habitat sediment data layers alone to determine the distribution and extent of these data within the study area delineated by the BGS wider seas data coverage (Figure 3.1). Whilst not definitive regarding the determination of potential spawning habitat alone (hence the 'heat' mapping) these data and the initial analyses were deemed appropriate by the EIA WG. This considers the fact that no area of 'heat' should have a level of confidence above low, if it is not underpinned by a suitable sediment type; either preferred or marginal habitat sediment[5]. This relates to the ecological importance of seabed sediments in structuring spawning beds.

Considering that the methodology to identify seabed with the potential to support spawning adopts a 'heat' mapping approach, then the results of analyses using just the habitat sediment data alone are arguably of little value when factoring the other data used; and wider environmental parameters that are currently un-mappable, such as micro-scale morphological features such as ripples or seabed sediment oxygenation. However, as the habitat sediments are a fundamental physical factor that underpins the determination of potential spawning habitat the analyses are presented for consideration. These are located in Appendix M of this report.

3.3. Comparison between the BGS and MAREA seabed sediment habitat data

Comparisons between the BGS and MAREA seabed habitat sediment extent data shows that the calculated values for the Humber and South Coast regions align; with similar representation of total habitat and also the division between preferred and marginal habitat sediments (Figure 3.6; see Appendix M for detail). In contrast there appears to be a level of disparity for both the Anglian and Outer Thames Estuary regions between the BGS and MAREA data. The MAREA data indicate a larger extent of preferred habitat sediment (Outer Thames) or marginal habitat sediment (Anglian) whereas the BGS data indicate similar extents of preferred habitat and marginal habitat sediments.

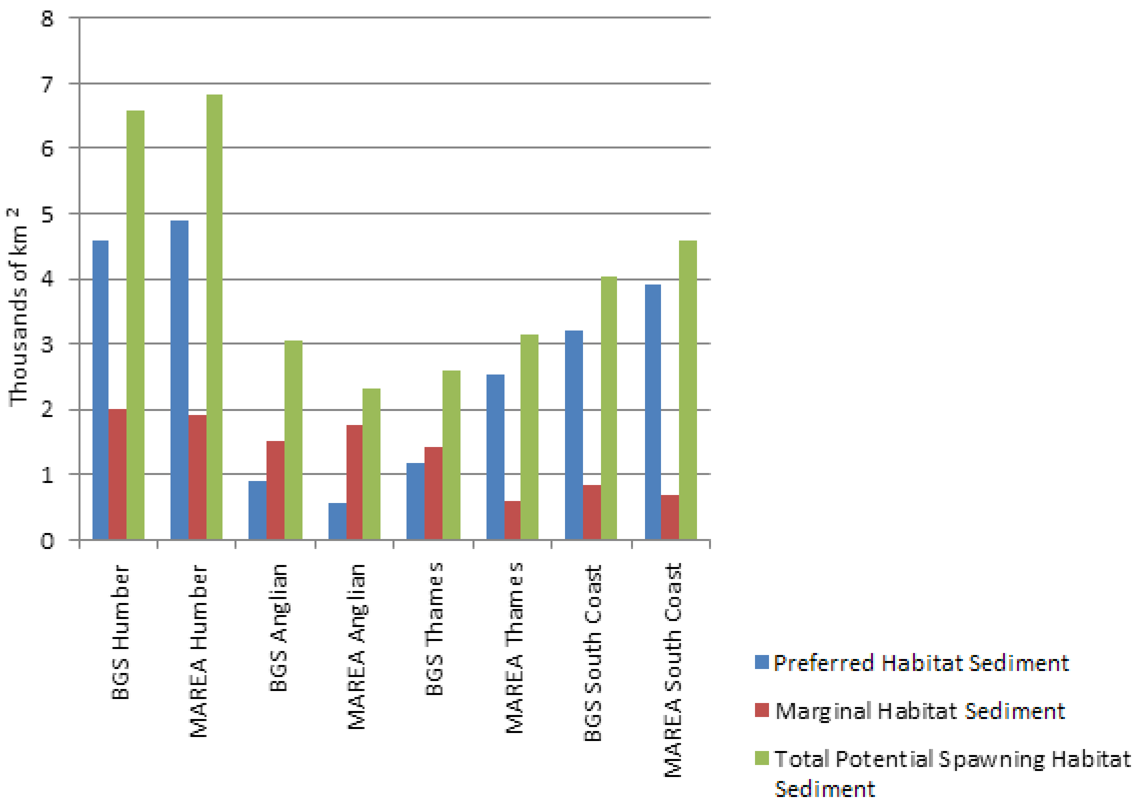
It is likely that some of the discrepancies between the BGS and MAREA seabed sediment data relate to data vintage and seabed bedform mobility e.g. a larger extent of marginal habitat sediments in the Anglian MAREA data in comparison with the BGS data may reflect both the more recent data acquisition and the known mobility of sandy sediments within that region (EMU Ltd, 2012a).

The different ways that the seabed sediments data have been presented in each of the respective MAREA study reports may contribute to any discrepancies between the MAREA and BGS data. For the Outer Thames Estuary and South Coast MAREAs certain Folk sediment classification divisions have been amalgamated to aid interpretation (ERM Ltd, 2010; EMU Ltd, 2012b). The Outer Thames Estuary MAREA combined the sandy Gravel and gravelly Sand divisions together as a single mapping

[5] The exception could theoretically be where IHLS data are available, but do not overlap preferred or marginal habitat sediment data (given the weighting score of 5 for the IHLS data). This does not actually occur within the analyses conducted

unit; whereas the South Coast MAREA combined the Gravel and sandy Gravel component of the Folk classification.

Figure 3.6: Comparison of the mapped extents of Atlantic Herring potential spawning habitat sediments: within the Humber, Anglian, Outer Thames Estuary and South Coast regions and between the BGS and MAREA data. (Derived from 1:250,000 scale BGS Digital Data under Licence 2013/063 British Geological Survey. ©NERC.; EMU Ltd, 2012a, 2012b; ERM Ltd, 2010, 2012)



Note that references to habitat relate to habitat <u>sediments</u> and are not an indicator of definitive habitat i.e. they relate to preferred habitat sediment and marginal habitat sediment and no considerations of habitat modifiers/additional parameters such as sediment oxygenation, micro-scale geomorphological features etc. have been applied

The MAREA sediment classifications were set up for the purpose of the MAREA assessments and remain fit for purpose for these tasks, but the presentation of the sediment data for the purposes of the Thames and South Coast MAREAs assessments means that they are not optimised for the purposes of the Atlantic Herring habitat screening assessment. The threshold between preferred and marginal spawning habitat sediment sits across the division between sandy Gravel and gravelly Sand (see Figure 2.1; Reach *et al.*, 2013; Appendix A). Therefore the Outer Thames Estuary MAREA, specifically, may over or under-represent either preferred or marginal habitat sediment. A review of Figure 3.6 suggests that it is likely that the Outer Thames Estuary MAREA data over-represents the preferred habitat sediment extent, therefore under-representing the area of marginal habitat sediment. In this instance the EIA WG determined that the BGS data allowed more meaningful resolution for spatial analyses at the MAREA-scale. For The South Coast MAREA, combining Gravel and sandy Gravel is less problematical as the preferred potential spawning habitat sediment for Atlantic Herring is represented by both these sediment divisions (Figure 2.1).

In the case of the South Coast the Marine Aggregate EIA WG decided to use the BGS data to allow a level of synergy between the mapping used in this study and that produced as part of a similar assessment of sandeel potential habitat sediment (MarineSpace *et al.*, 2013e). For sandeel the threshold between preferred and marginal habitat sediment sits across the division between Gravel and sandy Gravel (Latto *et al.*, 2013). Therefore the South Coast MAREA data is unsuitable to allow the distinction between preferred and marginal habitat sediment.

In all the above cases, where Folk sediment classes have been generalised or combined, the lowest confidence is adopted, e.g. the confidence of a combined class of sandy Gravel and gravelly Sand to indicate Atlantic Herring potential spawning habitat sediment is 0 (very low).

As it was not possible (or necessarily desirable) to combine both the BGS and MAREA seabed sediment data as an indicator of potential spawning grounds, the EIA WG has advised that the best seabed sediment data deemed appropriate are used within the study (and for any particular application area's ES). Therefore the combined confidence results are presented using the BGS and MAREA seabed sediment base-maps separately.

A comparison has been conducted per MAREA region between the BGS and MAREA seabed sediment base-maps, in order to ascertain the most appropriate spatial resolution to allow Stage 1 screening of application areas and Stage 2 regional CIA (see Figures M7-M10 in Appendix M). Considerations of the issues discussed above, and the overall confidence in each of the datasets (see Appendix B), have been taken into account when determining the most appropriate seabed sediment base-map to use. The resolution of the base-maps has been examined to identify which data best describe the boundaries between preferred and marginal habitat sediments, and bedforms and seabed geomorphological features. By comparing the MAREA and BGS seabed sediment maps at a regional scale, including the confidence assessment in those data (see Figures M6-M9 in Appendix M), the following seabed sediment data have been preferentially used within this study:

Region	Seabed Sediment Layer	Region	Seabed Sediment Layer
Humber	MAREA	**Outer Thames Estuary**	BGS
Anglian	MAREA	**South Coast**	BGS

3.4. International Herring Larvae Survey data

The International Herring Larvae Survey is coordinated by ICES and conducted annually by vessels from the Netherlands and Germany. The survey gives inference on the total biomass of autumn spawning Atlantic Herring in the North Sea (ICES, 2012).

The Stage 1 assessment considers any spatial overlap with the presence of Atlantic Herring yolk sac larvae (0-ringers), derived from suitable data sources such as the International Herring Larvae

Surveys (IHLS). Cefas fish ecologists have advised that larvae <10 mm for the central North Sea should be used to filter the spatial extent of potential spawning habitat and <11 mm for the southern North Sea, east English Channel and south coast (ECA and RPS, 2011; ICES, 2012; MMO, 2013).

It should be noted that the IHLS methodology assumes the best possible scientific practice available. However, Atlantic Herring larvae remain close to the seabed during the yolk-sac phase. The IHLS only samples down to 5 m above the seabed, and for this reason, yolk-sac and smaller larvae are not sampled effectively, as the towed plankton samplers used for the surveys are not deployed close enough to the seabed to capture the yolk-sac and smallest larvae. There is nothing that this study is able to do to rectify this sampling deficiency/artefact. Also, it should be noted that Atlantic Herring larvae sampling strategies for seabed developments such as offshore windfarms also tend to replicate the IHLS methodology. Therefore there is a standard under-sampling of the yolk-sac and smallest larvae prevalent within most scientific surveys. This artefact in the sampling methodology has a two-fold effect:

- IHLS data may overestimate the area of potential herring spawning habitat due to larval dispersal from the actual egg site/spawning bed. This increases the spatial footprint of the receptor envelope/footprint resulting in the likelihood of the assessment conducted in this report predicting an overlap between a licence area and a high value potential spawning area;
    - This results in a conservative assessment envelope as the extent of the spawning bed is effectively over-estimated; and conversely
- By overestimating the area of potential spawning habitat, the percentage overlap with aggregate extraction licence areas could be underestimated.

Considering the scale of each of the regional CIAs, along with the wider seas scale, it is reasonable to assume that the conservative assessment regarding dispersed larvae, especially considering the scale of the licence and application areas screened into the assessments, the precautionary assessment envelope (see Section 2.1) may act as a check to the possible underestimation of percentage overlap. Further, for higher ‘heat’ locations (medium and high ‘heat’ areas) then finer-scale investigations and increased resolution of site-specific data are likely to assist in the possible identification of seabed features that have the potential to act as spawning beds.

The IHLS data used in this study provides information for the years 2002-2011.

The IHLS data layers are used to enhance the information used in Stage 1, and are mapped over the preceding layers. These data, where available, are considered the most indicative of seabed areas with the potential to support Atlantic Herring spawning, as the surveys are specifically targeting Atlantic Herring larvae. As such the confidence in these data is the highest of any of the datasets used in this study (very high, score of 5).

It is important to note that there is limited IHLS data coverage for parts of the central and southern North Sea Atlantic Herring populations within UK Territorial Waters. The IHLS was greater in extent and duration in the past but it is reasonable to assume that when it was scaled down it was to focus on the most important areas. Still, significant areas of the Humber, south of Spurn Point, the inner

Anglian and parts of the inner Outer Thames marine aggregate regions fall outside the recent and current IHLS data coverage. However, it is important to note that in areas where the IHLS survey has not been undertaken is not indicative of no spawning. It is merely an artefact of the reduced coverage of the IHLS in recent times.

It should also be noted that for this assessment only two of the four North Sea populations are relevant and of these one, Downs, is still well studied today. Reference to Figures 3.1 and 3.2, shows that the known distribution of the Banks and Downs spawning populations, fall entirely within the IHLS survey grid. Further, Figure 3.1 shows the sample grid and null data points, where no larvae were sampled. This sets the context for the IHLS data used and enables a distinction between lack of survey data and null data to be made. In the case of data voids, other relevant data sources were searched for and identified. The only additional data with coverage for Atlantic Herring larvae distribution and marine aggregate regions were sourced from the Triton Knoll offshore windfarm project (RPS, 2011). Atlantic Herring larvae surveys were conducted in 2009 and 2011. These provide coverage for part of the Humber MAREA region and increase the data available for assessment for many of the 'inner' Humber region licence and application areas. The RPS data (2009 and 2011) was derived at a different period to the IHLS data for the same years, so a level of caution has to be applied when considering suitable coverage of the spawning events in the 'inner' Humber region. However, it is worth noting that these data have been reviewed by the RAG member agencies and overall have been used as part of the application process for Triton Knoll offshore windfarm. See Appendix L for further comments regarding IHLS data limitations.

The IHLS dataset was supplied in point format (stations) for all years 2002-2011, showing a number of fields. Following discussion with Cefas (Cefas, 2013a, 2013b; MMO, 2013a, 2013b, 2013c), the larvae abundance fields were rejected as these are dependent on the volume of water processed, which is related to the water depth. Instead, the number of larvae per square metre field was selected for the relevant larvae size range (<10 mm in the central North Sea and <11 mm in the eastern English Channel/southern North Sea).

Each sample or haul repeated the same no./m^2 for every length class, therefore, all duplicates were removed as the no./m^2 was indicative for the haul as a whole and not each length class. Secondly, spreadsheet formulae were used to amalgamate the data for all samples at the same location. This then calculated the number of samples within the time period for each station.

On review of the summarised data, in some cases, there was only one sample within a single year and in some cases only one year of data. As it cannot be confirmed that these data correlated with a spawning period, it was considered misleading to average out the no./m^2 field per location (based on the contributing samples). Instead, the maximum no./m^2 at any one location during the time period assessed, 2002-2011, was calculated for each location.

Also due to the potential issue of survey not corresponding with a spawning event, any locations where there were 3 samples, or fewer, in total over the period were removed from the dataset. This filtering improved the interpolation substantially as there were one or more surveys that did not align to the survey grid structure used in more recent IHLS surveys. The approach used has removed some bias in the data. To check that the resulting data were a suitable representation of the data overall, the dataset without any locations removed (i.e. <3 samples) was assessed against the filtered data (i.e. instances of >3 samples) and a good agreement between the two datasets was found.

The interpolation of the abundance (max no./m^2 within 2002-2011) was tested in ArcGIS for the available interpolation methods. Following various trials and comparison to the original point data, the Natural Neighbour method was considered most suitable and therefore applied to the point data (default settings).

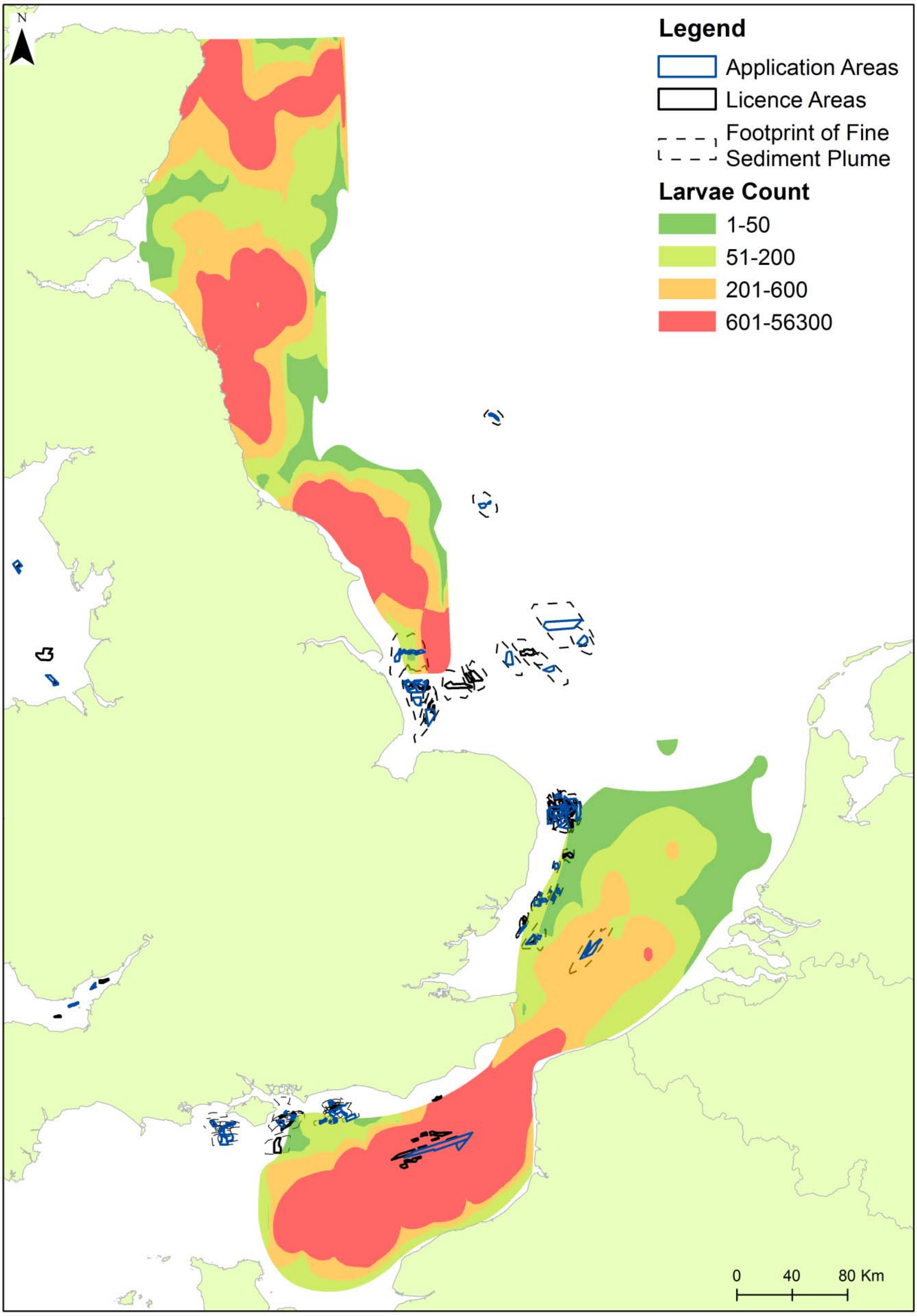
To convert the raster interpolation to shapefile, contour lines were created (vector polyline) in a separate file. This allowed the interpolated data to be mapped and spatially analysed with other data layers as part of the confidence assessment. Further detail concerning the interpolation of the IHLS (as agreed with Cefas) is contained within Appendix B.

Whilst the IHLS data are effectively used as direct indicators of larvae presence/absence, the interpolation of the larvae density has been conducted to evaluate if any areas of UK waters have a higher level of recorded spawning than others. Figure 3.7 shows the coverage of the IHLS and Triton Knoll offshore windfarm data and the interpolation. The relationship of the Banks and Downs populations can be seen (Banks in the central and southern North Sea and the Downs in the east English Channel) with distinct 'hotspots' within the recorded distribution of the larvae.

Figure 3.7 shows that the Banks population, and its recorded spawning area, extends far to the north of the Humber region, but actually has very little spatial overlap with marine aggregate licence and application areas in that region. Application Area 514 (including Licence Area 102 and 105) has a spatial overlap through both the PIZ and SIZ footprints.

For the Downs population there is a much higher incidence of spatial overlap between the PIZs and SIZs for numerous licence and application areas within the South Coast and Outer Thames Estuary and a small number in along the eastern limits of the Anglian region. The highest densities of larvae associated with the Downs population are concentrated in the east English Channel. All of the East Channel region licence and application areas fall within densities of larvae in the range of 601-56,300 individuals (Figure 3.7; ECA and RPS, 2010a, 2010b, 2011). It is important to note that the East Channel region is not assessed as part of this study, and is considered under its own potential spawning habitat methodology and assessment process (ECA, 2011; ECA and RPS, 2010a, 2010b, 2011).

Figure 3.7: Interpolation of International Herring Larvae Survey data for the period 2002-2011. (Derived from ICES IHLS data for 2002-2011)



3.5. Stage 1 Results – Screening of licence and application areas

The 'heat' maps (resulting from the multiple GIS data layer overlaps) allow a spatial assessment of receptor-pressure-exposure pathways to be described and analysed. These maps are presented in appendices for each of the four marine aggregate regions considered as part of this study:

- Appendix C: the Humber region;
- Appendix D: the Humber 'outlier' region;
- Appendix E: the Anglian region;
- Appendix F: the Outer Thames Estuary region; and
- Appendix G: the South Coast region.

The appendices present interactive maps showing the individual data layers considered to represent indication of potential spawning habitat, and the attendant confidence/'heat' score associated with the data.

Each data layer is presented and the spatial interaction with the PIZ and SIZ footprints for the licence and application areas are illustrated.

A total combined data 'heat' map is presented using either BGS or MAREA seabed sediment base-maps as appropriate:

- MAREA seabed sediment base-map for the Humber and Anglian regions; and
- BGS seabed sediment base-map for the Outer Thames Estuary and South Coast regions.

The 'heat map' shows the probability, for any seabed location, of the presence of potential spawning habitat to be present, or for an area to support spawning activity.

Any area of spatial overlap between a licence area or an application area and any of the data layers will result in that particular area screened into requiring an environmental assessment. Application areas will require an EIA to assess the significance of the exposure footprint. Existing licence areas will be screened in and identified as contributing to the Stage 2 regional CIA.

Licence and application areas outside of MAREA regions ('outlier' areas) have also been screened for the requirement of environmental assessment and compliance with the MWR. Whilst these are not considered as part of the MAREA-scale CIA, any application area screened in will require an EIA to assess the significance of environmental effects, including cumulative and in-combination effects. Existing 'outlier' licence areas are screened to facilitate consideration of cumulative and in-combination assessments with adjacent 'outlier' application areas, where appropriate or required.

The following sub-sections present a screening table that has been compiled from the data layers and the confidence in each layer. The tables indicate where there is any spatial overlap with each data layer, using the relevant confidence score for that layer. A total combined score is provided and then an indication of whether the licence or application area is screened into requiring further environmental assessment (EIA for application areas and consideration as contributing to part of a cumulative and in-combination assessments). The screening assessment considers an area's PIZ and SIZ separately to better inform any subsequent assessment i.e. an application area's PIZ may have zero overlap with any of the data layers and thus be screened out. However there may be a spatial overlap between that application area's SIZ and data layers, in which case the area will be screened into requiring further environmental assessment.

Any spatial overlap will result in a licence or application area being screened into requiring an environmental assessment, regardless of the probability or confidence score associated with the overlap. It is for the EIA process to determine the significance and magnitude of any impacts that may result from any spatial interactions between the application area and the Atlantic Herring potential spawning habitat at that location and within the MAREA-scale context.

3.5.1. Humber region

Figures 3.8a and b illustrate the positions of the licence and application areas assessed for the Humber region, while Figures 3.9 and 3.10 overlay these areas on the confidence 'heat' map for Atlantic Herring potential spawning habitat. It is clear that the regions of highest confidence (i.e. confidence score 9-12 inclusive) are those areas of seabed where IHLS data positively identify Atlantic Herring spawning. This is most notable in the northern part of the region, inshore along the Holderness coast. Analysis of the RPS (2011) Triton Knoll offshore windfarm Atlantic Herring Larvae survey data extends the coverage of IHLS data across the Humber region and provides confidence that the extent of the data reflects actual distribution of larvae, mitigating a lack of ICES IHLS sampling south of Spurn Point (ICES, 2012) i.e. the extent of the larvae is not limited by ICES IHLS data gaps.

Figures 3.9 and 3.10, and Tables 3.1 and 3.2 show that the majority of licence and application areas overlap regions of low and medium 'heat'. The Coull *et al.* (1998) spawning layer extends further south into the region than the IHLS data and overlaps with the marine aggregate areas offshore from the Lincolnshire coast.

Another area of seabed associated with the Coull *et al.* (1998) spawning layer is located to the north of Areas 492 and 408, and overlaps with the SIZ footprints for these areas. The PIZs and SIZs for Areas 105, 514/2, 514/3 and 514/4 overlie high confidence regions, while the SIZs for Areas 106/1, 106/2, 106/3, 197, 400, 480, and 493 also overlap high confidence regions.

Cefas has indicated that there is an area of spawning located well outside of the study area off the north Norfolk coast that may be utilised by Atlantic Herring for spawning in the spring "*Identifying where spawning might occur is difficult as the area is data poor and spawning site fidelity is likely to be inconsistent.*" (Cefas, 2013b). Further, Cefas (2013b) state that:

"*Spring spawning herring also utilise grounds off the Lincolnshire coast and in the Wash. Information on this area is anecdotal and data poor. However, spring spawning herring were captured in surveys undertaken by the Hornsea Project 1 wind farm highlighting that these herring are present in the area.*"

All areas within the Humber region, including the 'outlier' licence and application areas are screened in for assessment at site-specific EIA level (Table 3.1, Table 3.2).

Figure 3.8a: Licence and application areas within the Humber region considered within the screening and assessment study. (Source: The Crown Estate, 2013)

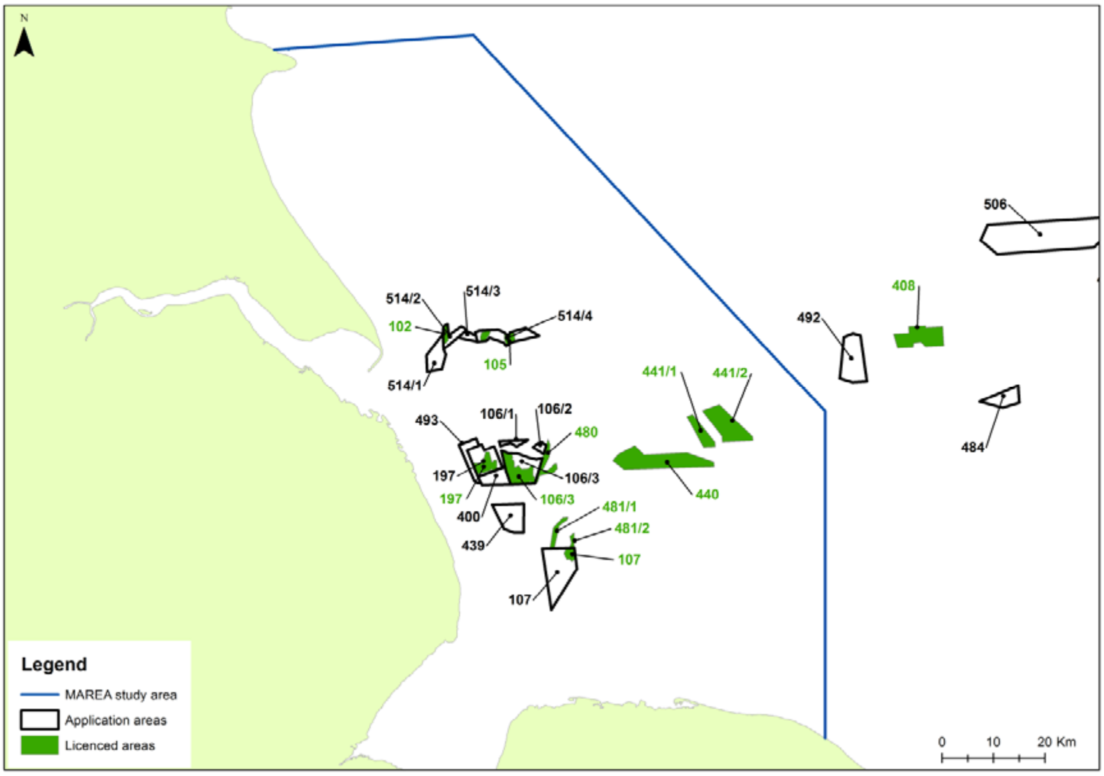


Figure 3.8b: 'Outlier' licences and application areas within the Humber region considered within the screening and assessment study. (Source: The Crown Estate, 2013)

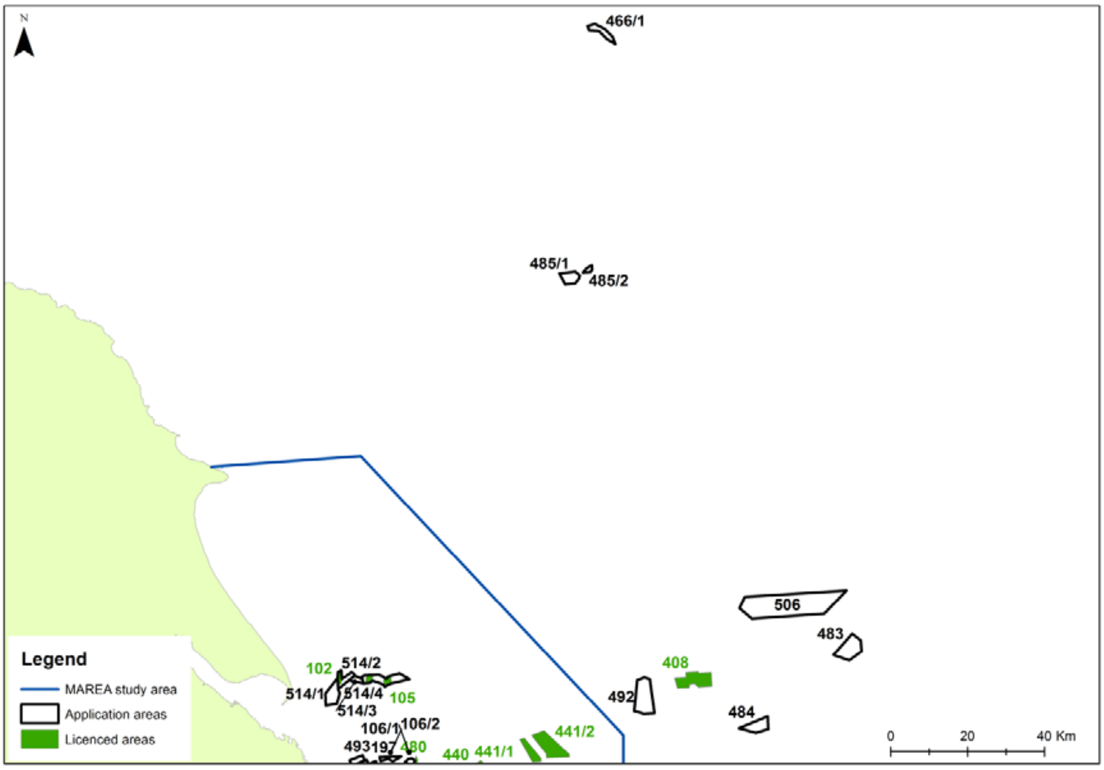


Figure 3.9: Humber Marine Aggregate Regional Environmental Assessment total combined data layer map.

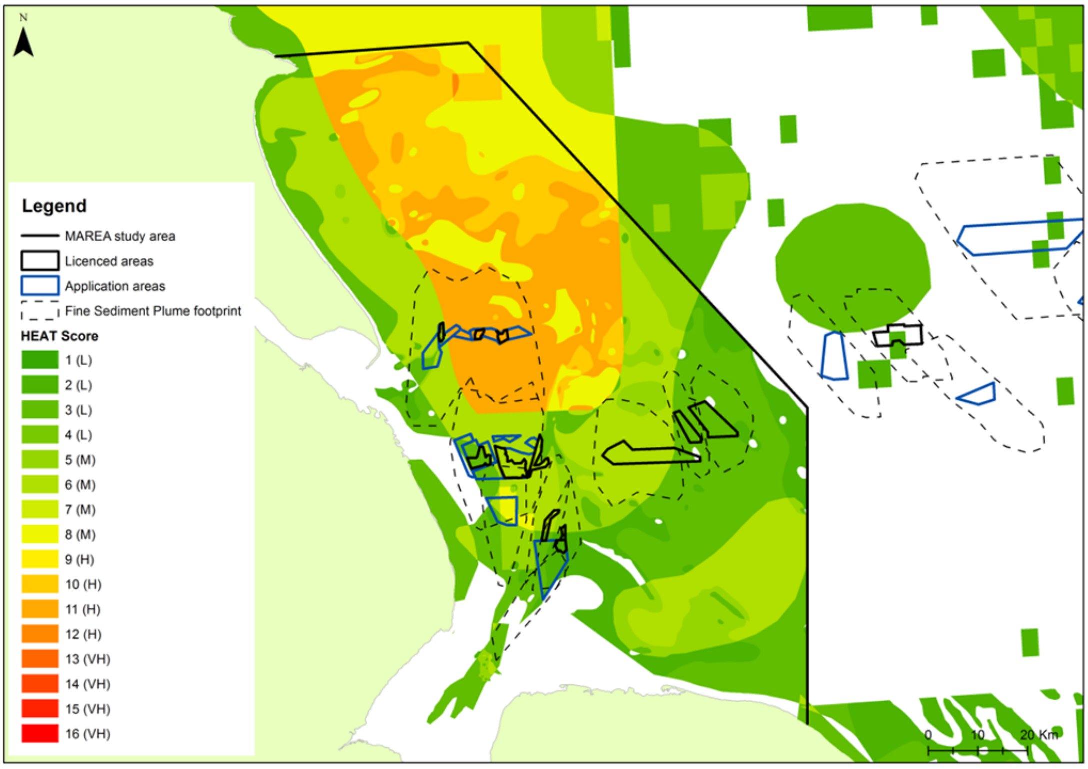


Figure 3.10: Humber region 'Outlier' Marine Aggregate Regional Environmental Assessment total combined data layer map.

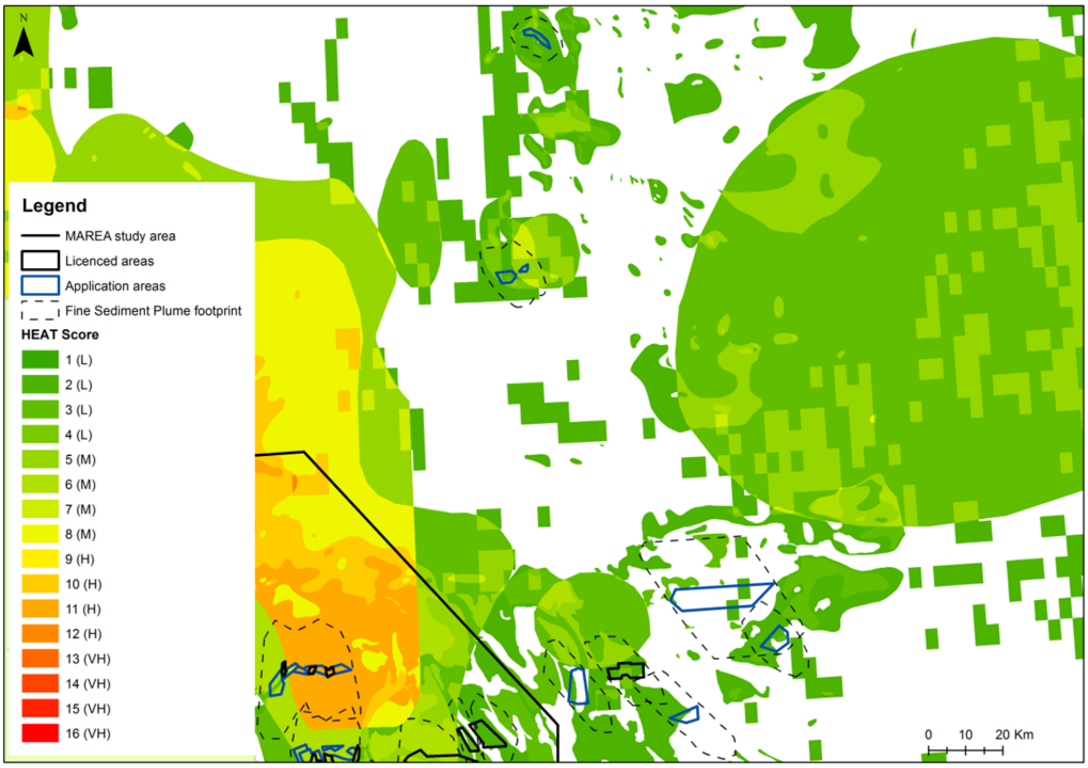


Table 3.1: Screening of Humber region renewal and application areas

Area (Status)	Licence Name (Operator)	Impact Zone	Habitat sediment Type: Preferred		Habitat sediment Type: Marginal	Coull *et al.* (1998)	ESFJC	VMS	IHLS	In	Out
466/1 (Application)	**North West Rough** (CEMEX UK Marine Ltd)	PIZ	✓		✓					In	
		SIZ	✓		✓			✓		In	
485/2 (Application)	**Southernmost Rough** (CEMEX UK Marine Ltd)	PIZ			✓	✓				In	
		SIZ			✓	✓		✓		In	
485/1 (Application)	**Southernmost Rough** (CEMEX UK Marine Ltd)	PIZ	✓		✓			✓		In	
		SIZ	✓		✓			✓		In	
506 (Application)	**Humber 4 and 7** (DEME Building Materials Ltd)	PIZ						✓		In	
		SIZ	✓	✓	✓			✓		In	
483 (Application)	**Humber 5** (DEME Building Materials Ltd)	PIZ	✓	✓	✓					In	
		SIZ	✓	✓	✓					In	
514/3 (formerly 449) (Application)	**New Sand Hole and Humber Extension** (CEMEX UK Marine Ltd)	PIZ	✓			✓			✓	In	
		SIZ	✓			✓			✓	In	
514/1 (formerly 448) (Application)	**New Sand Hole and Humber Extension** (CEMEX UK Marine Ltd)	PIZ	✓			✓				In	
		SIZ	✓			✓			✓	In	
492 (Application)	**Sole Pit** (Hanson Aggregates Marine Ltd)	PIZ			✓					In	
		SIZ	✓		✓					In	
484 (Application)	**Humber 3** (DEME Building Materials Ltd)	PIZ			✓					In	
		SIZ			✓			✓		In	

493 (Application)	**Humber Overfalls** (Lafarge Tarmac Marine Ltd)	PIZ	✓		✓				In	
		SIZ	✓	✓	✓			✓	In	
400 (Application)	**North Dowsing** (Hanson Aggregates Marine Ltd)	PIZ	✓	✓	✓				In	
		SIZ	✓	✓	✓			✓	In	
439 (Application)	**Inner Dowsing** (Hanson Aggregates Marine Ltd)	PIZ	✓		✓		✓		In	
		SIZ	✓		✓		✓		In	
514/2 (formerly 102) (Application)	**Humber Estuary** (CEMEX UK Marine Ltd)	PIZ	✓		✓			✓	In	
		SIZ	✓		✓			✓	In	
106/1 (Application)	**Humber Estuary** (Hanson Aggregates Marine Ltd)	PIZ	✓		✓				In	
		SIZ	✓	✓	✓			✓	In	
106/2 (Application)	**Humber Estuary** (Hanson Aggregates Marine Ltd)	PIZ	✓		✓				In	
		SIZ	✓		✓			✓	In	
197 (Application)	**Off Saltfleet** (Lafarge Tarmac Marine Ltd)	PIZ	✓		✓				In	
		SIZ	✓	✓	✓			✓	In	
106/3 (Application)	**Humber Estuary** (Hanson Aggregates Marine Ltd)	PIZ	✓		✓				In	
		SIZ	✓		✓			✓	In	
514/4 (formerly 105) (Application)	**Humber Estuary** (CEMEX UK Marine Ltd)	PIZ	✓		✓			✓	In	
		SIZ	✓		✓			✓	In	
107 (Application)	**South Inner Dowsing** (CEMEX UK Marine Ltd)	PIZ		✓					In	
		SIZ	✓	✓		✓			In	

Table 3.2: Screening of Humber region licence areas

Area (Status)	Licence Name (Operator)	Impact Zone	Habitat sediment Type		Coull *et al.* (1998)	ESFJC	VMS	IHLS	In	Out
			Preferred	Marginal						
102 (Licence)	**West Humber** (British Dredging Ltd)	PIZ	✓		✓				In	
		SIZ	✓		✓			✓	In	
408 (Licence)	**Coal Pit** (Hanson Aggregates Marine Ltd)	PIZ		✓			✓		In	
		SIZ		✓	✓		✓		In	
441/2 (Licence)	**Outer Dowsing** (Westminster Gravels Ltd)	PIZ		✓					In	
		SIZ	✓	✓	✓				In	
441/1 (Licence)	**Outer Dowsing** (Westminster Gravels Ltd)	PIZ	✓						In	
		SIZ	✓	✓	✓				In	
480 (Licence)	**106 East** (Hanson Aggregates Marine Ltd)	PIZ	✓		✓				In	
		SIZ	✓		✓			✓	In	
197 (Licence)	**Protector Overfalls** (Lafarge Tarmac Marine Ltd)	PIZ	✓		✓				In	
		SIZ	✓	✓	✓			✓	In	
440 (Licence)	**Outer Dowsing** (Westminster Gravels Ltd)	PIZ	✓	✓	✓				In	
		SIZ	✓	✓	✓			✓	In	
106/3 (Licence)	**Wash** (Hanson Aggregates Marine Ltd)	PIZ	✓		✓				In	
		SIZ	✓		✓			✓	In	
481/1 (Licence)	**Inner Dowsing** (Van Oord Ltd)	PIZ		✓	✓				In	
		SIZ		✓	✓				In	
481/2 (Licence)	**Inner Dowsing** (Van Oord Ltd)	PIZ		✓	✓				In	
		SIZ	✓	✓	✓				In	
107 (Licence)	**South Inner Dowsing** (British Dredging Ltd)	PIZ		✓					In	
		SIZ		✓	✓				In	

481/1 (Licence)	**Inner Dowsing** (Lafarge Tarmac Marine Ltd)	PIZ		✓	✓				In	
		SIZ		✓	✓		✓		In	
481/2 (Licence)	**Inner Dowsing** (Lafarge Tarmac Marine Ltd)	PIZ		✓	✓				In	
		SIZ	✓	✓	✓				In	
105 (Licence)	**East Humber** (British Dredging Ltd)	PIZ	✓		✓			✓	In	
		SIZ	✓		✓			✓	In	

3.5.2. Anglian region

Figure 3.11 illustrates the locations of the licence and application areas assessed for the Anglian region, while Figures 3.12 and 3.13 overlay these areas on the confidence 'heat' map for Atlantic Herring potential spawning habitat. It is clear that the regions of high 'heat' (i.e. confidence score 9-12 inclusive) are those areas of seabed where IHLS data positively identify Atlantic Herring spawning. This is most notable in the eastern limits of the region, predominantly further offshore away from the main concentration of licence and application areas. Areas 495/2 and 401/2A have a degree of partial overlap with these high confidence areas of seabed. The southern-most licence, Area 430, and application Area 496, also have a spatial overlap with the IHLS data layer, with Area 430 interacting with a high 'heat' location, whilst 496 overlays and area of medium 'heat'. The SIZ associated with Area 401/2B has a spatial overlap with a location of high 'heat' associated with the IHLS data layer.

Figures 3.12 and 3.13, and Tables 3.3 and 3.4 show that the majority of licence and application areas overlap low 'heat' areas of seabed. The Coull *et al.* (1998) spawning layer is located inshore of the majority of the licence and application area block and is distant from the IHLS data, overlapping with the PIZs and SIZs of Areas 240, 254, 251, 319 and 511.

Whilst application Area 361/2 has no PIZ overlap with any of the data layers, its SIZ does interact with both preferred and marginal potential spawning habitat sediment and is therefore screened in. Therefore, all areas within the Anglian region are screened in for assessment at site-specific EIA level (Table 3.3, Table 3.4).

Figure 3.11: Licence and application areas within the Anglian region considered within the screening and assessment study. (Source: The Crown Estate, 2013)

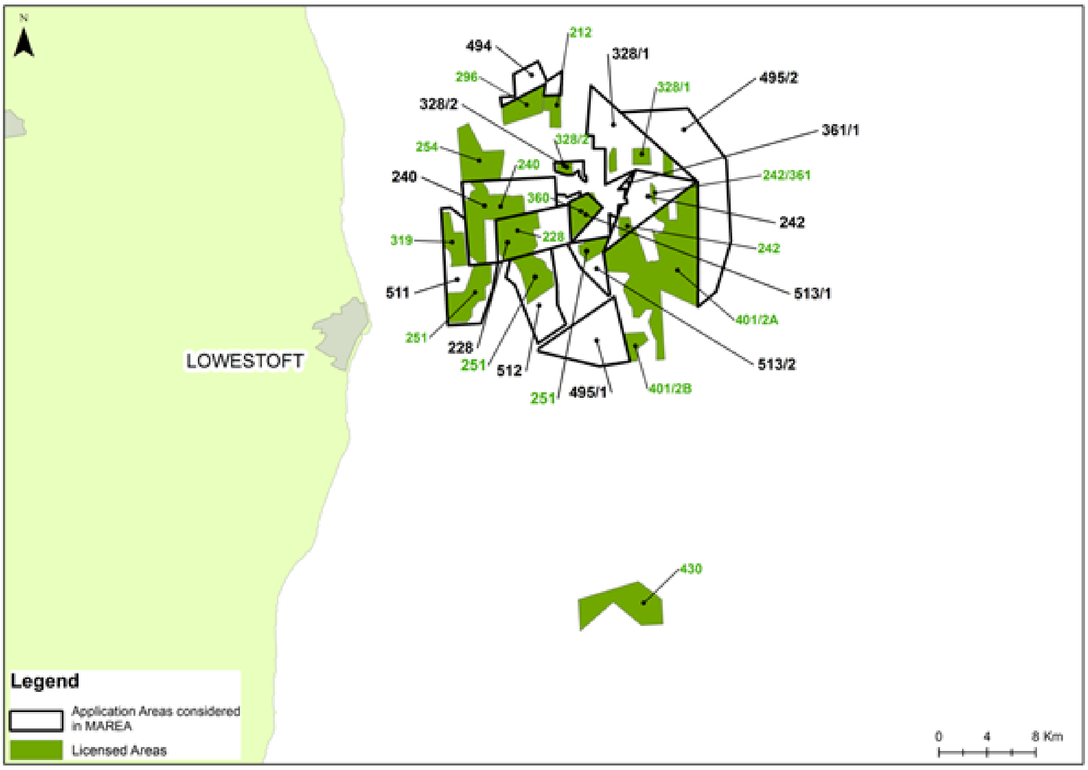


Figure 3.12: Anglian Marine Aggregate Regional Environmental Assessment total combined data layer map.

Figure 3.13: Zoomed in on the Anglian Marine Aggregate Regional Environmental Assessment total combined data layer map (note excludes Areas 430 and 496).

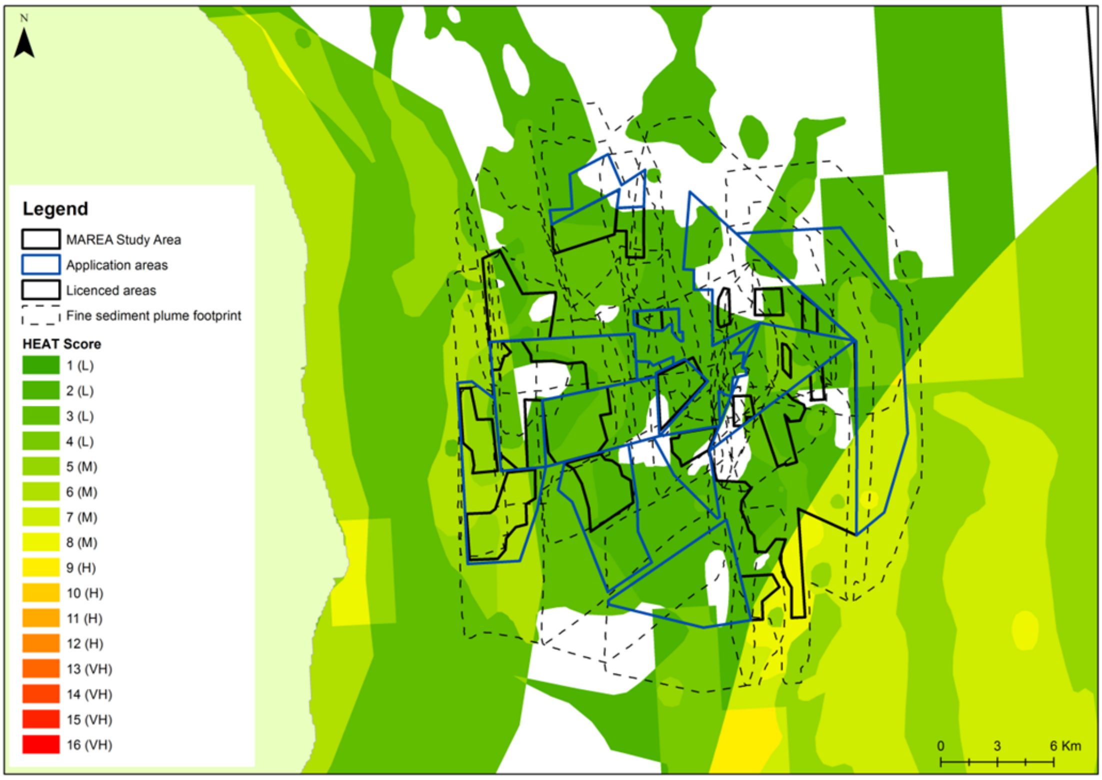


Table 3.3: Screening of Anglian region renewal and application areas.

Area (Status)	Licence Name (Operator)	Impact Zone	Habitat sediment Type: Preferred	Habitat sediment Type: Marginal	Coull *et al.* (1998)	ESFJC	VMS	IHLS	In	Out
494 (Application)	**North Cross Sands** (Lafarge Tarmac Marine Ltd)	PIZ		✓					In	
		SIZ	✓	✓					In	
495/2 (Application)	**Lowestoft Extension** (Hanson Aggregates Marine Ltd)	PIZ		✓			✓	✓	In	
		SIZ		✓			✓	✓	In	
495/1 (Application)	**Lowestoft Extension** (Hanson Aggregates Marine Ltd)	PIZ	✓	✓			✓		In	
		SIZ	✓	✓			✓	✓	In	
		SIZ		✓				✓	In	

513/1 (Application)	**TBC** (CEMEX UK Marine Ltd)	PIZ		✓					In	
		SIZ		✓					In	
511 (Application)	**TBC** (CEMEX UK Marine Ltd)	PIZ	✓	✓	✓				In	
		SIZ	✓	✓	✓				In	
513/2 (Application)	**TBC** (CEMEX UK Marine Ltd)	PIZ	✓	✓					In	
		SIZ	✓	✓					In	
512 (Application)	**TBC** (CEMEX UK Marine Ltd)	PIZ	✓	✓					In	
		SIZ	✓	✓					In	
328/1 (Application)	**Off Great Yarmouth** (Hanson Aggregates Marine Ltd)	PIZ		✓			✓		In	
		SIZ	✓	✓			✓		In	
328/2 (Application)	**Off Great Yarmouth** (Hanson Aggregates Marine Ltd)	PIZ		✓					In	
		SIZ	✓	✓					In	
361/1 (Application)	**Cross Sands** (Hanson Aggregates Marine Ltd)	PIZ		✓					In	
		SIZ	✓	✓					In	
242 (Application)	**Cross Sands** (Hanson Aggregates Marine Ltd)	PIZ	✓	✓			✓		In	
		SIZ	✓	✓			✓		In	
240 (Application)	**Off Great Yarmouth Extension** (Hanson Aggregates Marine Ltd)	PIZ	✓	✓	✓				In	
		SIZ	✓	✓	✓				In	
328/3 (Application)	**Off Great Yarmouth** (Hanson Aggregates Marine Ltd)	PIZ		✓					In	
		SIZ	✓	✓					In	
228 (Application)	**Off Great Yarmouth** (Volker Dredging Ltd)	PIZ	✓	✓	✓				In	
		SIZ	✓	✓	✓				In	
361/2 (Application)	**Cross Sands** (Hanson Aggregates Marine Ltd)	PIZ								Out
		SIZ	✓	✓					In	
361/3 (Application)	**Cross Sands** (Hanson Aggregates Marine Ltd)	PIZ		✓					In	
		SIZ		✓					In	

Table 3.4: Screening of Anglian region licence areas.

Area (Status)	Licence Name (Operator)	Impact Zone	Habitat sediment Type: Preferred	Habitat sediment Type: Marginal	Coull *et al.* (1998)	ESFJC	VMS	IHLS	In	Out
296 (Licence)	**Cross Sands** (Lafarge Tarmac Marine Ltd)	PIZ	✓	✓					In	
		SIZ	✓	✓					In	
328/1 (Licence)	**East Norfolk** (Hanson Aggregates Marine Ltd)	PIZ		✓			✓		In	
		SIZ		✓			✓		In	
212 (Licence)	**Norfolk** (Hanson Aggregates Marine Ltd)	PIZ	✓	✓					In	
		SIZ	✓	✓					In	
254 (Licence)	**Off Great Yarmouth** (Lafarge Tarmac Marine Ltd)	PIZ	✓	✓	✓				In	
		SIZ	✓	✓	✓				In	
328/2 (Licence)	**East Norfolk** (Hanson Aggregates Marine Ltd)	PIZ		✓			✓		In	
		SIZ	✓	✓			✓		In	
360 (Licence)	**East Lowestoft** (CEMEX UK Marine Ltd)	PIZ		✓					In	
		SIZ		✓					In	
240 (Licence)	**Cross Sands** (Hanson Aggregates Marine Ltd)	PIZ	✓	✓	✓				In	
		SIZ	✓	✓	✓				In	
319 (Licence)	**North Lowestoft** (British Dredging Ltd)	PIZ	✓	✓	✓				In	
		SIZ	✓	✓	✓				In	
401/2A (Licence)	**Yarmouth** (Hanson Aggregates Marine Ltd)	PIZ	✓	✓			✓	✓	In	
		SIZ	✓	✓			✓	✓	In	
228 (Licence)	**Off Great Yarmouth** (Volker Dredging Ltd)	PIZ	✓	✓					In	
		SIZ	✓	✓					In	
251 (Licence)	**South Lowestoft** (British Dredging Ltd)	PIZ	✓	✓	✓				In	
		SIZ	✓	✓	✓				In	

401/2B (Licence)	**Yarmouth** (Hanson Aggregates Marine Ltd)	PIZ	✓	✓			✓	In	
		SIZ	✓	✓			✓	In	
430 (Licence)	**Southwold East** (CEMEX UK Marine Ltd)	PIZ	✓	✓			✓	In	
		SIZ	✓	✓			✓	In	
430 (Licence)	**Southwold East** (Lafarge Tarmac Marine Ltd)	PIZ	✓	✓			✓	In	
		SIZ	✓	✓			✓	In	
242 (Licence)	**Lowestoft** (Hanson Aggregates Marine Ltd)	PIZ	✓	✓		✓		In	
		SIZ	✓	✓		✓		In	
242/361 (Licence)	**Lowestoft** (Hanson Aggregates Marine Ltd)	PIZ		✓		✓		In	
		SIZ	✓	✓		✓		In	

3.5.3. Outer Thames Estuary region

Figure 3.14 illustrates the positions of the licence and application areas assessed for the Outer Thames Estuary region, while Figure 3.15 overlays these areas on the confidence 'heat' map for Atlantic Herring potential spawning habitat. It is clear that the regions of high 'heat' are those areas of seabed where IHLS data positively identify Atlantic Herring spawning. This is most notable across the majority of the region with only the PIZs of the inner region Licence Area 447 and Application Area 509/2 not overlain by IHLS data. However the SIZ for Area 509/2 shows a small spatial overlap with the IHLS footprint.

Figure 3.15, and Tables 3.5 and 3.6 show that the majority of licence and application areas overlap medium 'heat' regions. The Coull *et al.* (1998) spawning layer exists as a band across the outer part of the region and overlaps with the IHLS most significantly in the location of application Area 501/1 and 501/2. At this location there is a high 'heat' (confidence/probability) that the seabed has the potential to be Atlantic Herring spawning habitat. However it should be noted that the 'hottest' areas within this data overlap have a contribution from VMS data and these locations do not extend across the entirety of the 501/1 and 501/2 application area.

The PIZs and SIZs for Areas 501/1, 501/2, 507/5, 507/6, and 498 overlie high 'heat' areas of seabed.

Cefas have advised that there are known spring spawning grounds for Atlantic Herring in the Thames Estuary, on Eagle bank, (and Studhill Bank outside of the MAREA) and in the River Blackwater estuary (Cefas, 2013b). These areas are distant from marine aggregate licence and application areas and unlikely to be affected by the existing and proposed operations. Autumn spawning Downs Atlantic Herring grounds are located in the east of the region and are sampled by IHLS.

All areas within the Outer Thames Estuary region, including the 'outlier' application areas are screened in for assessment at site-specific EIA level (Table 3.5, Table 3.6).

Figure 3.14: Licence and application areas within the Outer Thames Estuary region considered within the screening and assessment study. (Source: The Crown Estate, 2013)

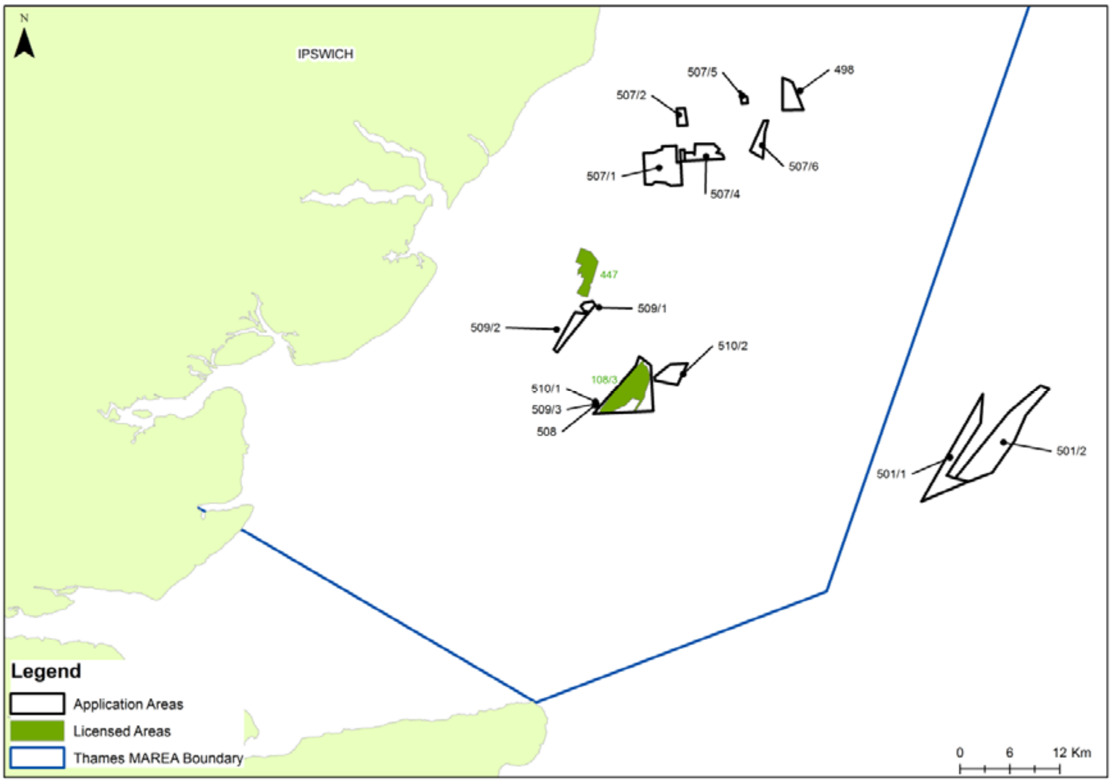


Figure 3.15: Outer Thames Estuary British Geological Survey total combined data layer map.

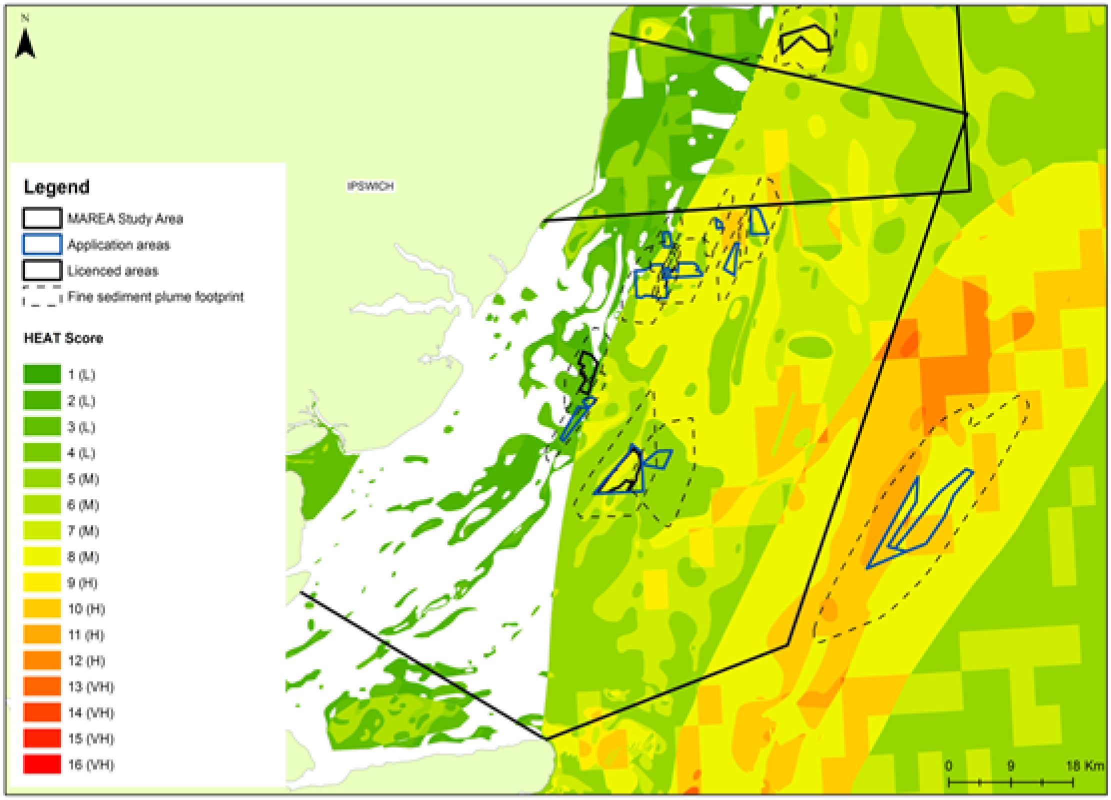


Table 3.5: Screening of Outer Thames Estuary region renewal and application areas.

Area (Status)	Licence Name (Operator)	Impact Zone	Habitat sediment Type: Preferred	Habitat sediment Type: Marginal	Coull *et al.* (1998)	ESFJC	VMS	IHLS	In	Out
507/5 (Application)	**Shipwash** (CEMEX UK Marine Ltd)	PIZ	✓				✓	✓	In	
		SIZ	✓				✓	✓	In	
507/2 (Application)	**Shipwash** (CEMEX UK Marine Ltd)	PIZ	✓					✓	In	
		SIZ	✓					✓	In	
507/4 (Application – Renewal)	**Shipwash** (CEMEX UK Marine Ltd)	PIZ	✓					✓	In	
		SIZ	✓					✓	In	
507/1 (Application – Renewal)	**Shipwash** (CEMEX UK Marine Ltd)	PIZ	✓					✓	In	
		SIZ	✓	✓				✓	In	
507/3 (Application – Renewal)	**Shipwash** (CEMEX UK Marine Ltd)	PIZ	✓					✓	In	
		SIZ	✓					✓	In	
508 (Application – Renewal)	**Longsand** (Britannia Aggregates Ltd)	PIZ	✓	✓				✓	In	
		SIZ	✓	✓				✓	In	
509/1 (Application – Renewal)	**Longsand** (Lafarge Tarmac Marine Ltd)	PIZ	✓					✓	In	
		SIZ	✓	✓				✓	In	
509/2 (Application – Renewal)	**Longsand** (Lafarge Tarmac Marine Ltd)	PIZ	✓	✓				✓	In	
		SIZ	✓	✓				✓	In	
509/3 (Application – Renewal)	**Longsand** (Lafarge Tarmac Marine Ltd)	PIZ	✓	✓				✓	In	
		SIZ	✓	✓				✓	In	
510/1 (Application – Renewal)	**Longsand** (CEMEX UK Marine Ltd)	PIZ	✓	✓				✓	In	
		SIZ	✓	✓				✓	In	
510/2 (Application – Renewal)	**Longsand** (CEMEX UK Marine Ltd)	PIZ	✓	✓				✓	In	
		SIZ	✓	✓				✓	In	
507/6 (Application)	**Shipwash** (CEMEX UK Marine Ltd)	PIZ	✓	✓			✓	✓	In	
		SIZ	✓	✓			✓	✓	In	
498 (Pre Application)	**North Inner Gabbard** (Britannia Aggregates Ltd)	PIZ	✓	✓				✓	In	
		SIZ	✓	✓			✓	✓	In	

498 (Pre Application)	**North Inner Gabbard** (Volker Dredging Ltd)	PIZ	3	+	2	+	0	+	0	+	0	+	5	= 10	In
		SIZ	3	+	2	+	0	+	0	+	2	+	5	= 12	In

Table 3.6: Screening of Outer Thames Estuary region licence areas.

Area (Status)	Licence Name (Operator)	Impact Zone	Habitat sediment Type: Preferred	Habitat sediment Type: Marginal	Coull *et al.* (1998)	ESFJC	VMS	IHLS	In	Out
447 (Licence)	**Cutline** (Hanson Aggregates Marine Ltd)	PIZ	✓	✓					In	
		SIZ	✓	✓				✓	In	
108/3 (Licence)	**Longsand** (Britannia Aggregates Ltd)	PIZ	✓	✓				✓	In	
		SIZ	✓	✓				✓	In	
447 (Licence)	**Cutline** (CEMEX UK Marine Ltd)	PIZ	✓	✓					In	
		SIZ	✓	✓				✓	In	
447 (Licence)	**Cutline** (Lafarge Tarmac Marine Ltd)	PIZ	✓	✓					In	
		SIZ	✓	✓				✓	In	

3.5.4. South Coast region

Figure 3.16 illustrates the positions of the licence and application areas assessed for the South Coast region, while Figure 3.17 overlays these areas on the confidence 'heat' map for Atlantic Herring potential spawning habitat. It is clear that the regions of high 'heat' are those areas of seabed where IHLS data positively identify Atlantic Herring spawning. This is most notable across the south-eastern part of the region extending offshore into to the East English Channel region (see Figure 1.1. for location). Therefore the majority of the licence and application areas overlap low 'heat' (Figure 3.17).

The PIZs and SIZs application Areas 122/D, 123/D, 122/E, 123/E, 122/F, 123/F, 122/G, 123/G, and 499 all overlap seabed areas associated with IHLS data. The PIZs for Licence Area 351 and 451 and Application Area 351 are also overlain by the IHLS data layer. Additionally the SIZs of Licence Areas 395/1 and 395/2 overlap the northwestern limits of the IHLS layer, and 407 SIZ interacts with the western limit of that spawning indicator layer. These impact zones are mostly associated with areas of seabed with medium 'heat' constituting potential spawning habitat, although Areas 122/E, 123/E, 122/G, 123G, and 499 have PIZs that overlap seabed with a high 'heat' area of seabed. The SIZ associated with Licence Area 407 also overlaps an area of high 'heat'. These areas of seabed are scored a combined high 'heat' due to an additional overlap with VMS data.

Figure 3.17, and Tables 3.7 and 3.8 show that the entirety of the West of Isle of Wight sub-region (Licence Areas 127 and 137 and Application Areas 127, 137, 500/1, 500/2, 500/3, 500/4, 500/5, and 500/6) occupies a seabed area of low 'heat' for Atlantic Herring potential spawning habitat. This sub-region appears to be well beyond the spawning area associated with the Downs population of Atlantic Herring with a low coincidence of VMS data.

It is notable that there are no Coull *et al.* (1998) data for the South Coast region so the overall maximum combined score is less than for the three other regions.

Cefas (2013b) has advised that "*No known herring spawning grounds are present within the area occupied by aggregate areas on the south coast.*" Considering the data and analyses conducted within this study, this determination appears to be incorrect, considering the IHLS data layer overlap with 9 licence or application areas (including SIZ for Area 499). These licence and application areas have been screened into the Stage 2 assessment.

Therefore, all areas within the South Coast region are screened in for assessment at site-specific EIA level (Table 3.7, Table 3.8).

Figure 3.16: Licence and application areas within the South Coast region considered within the screening and assessment study. (Source: The Crown Estate, 2013)

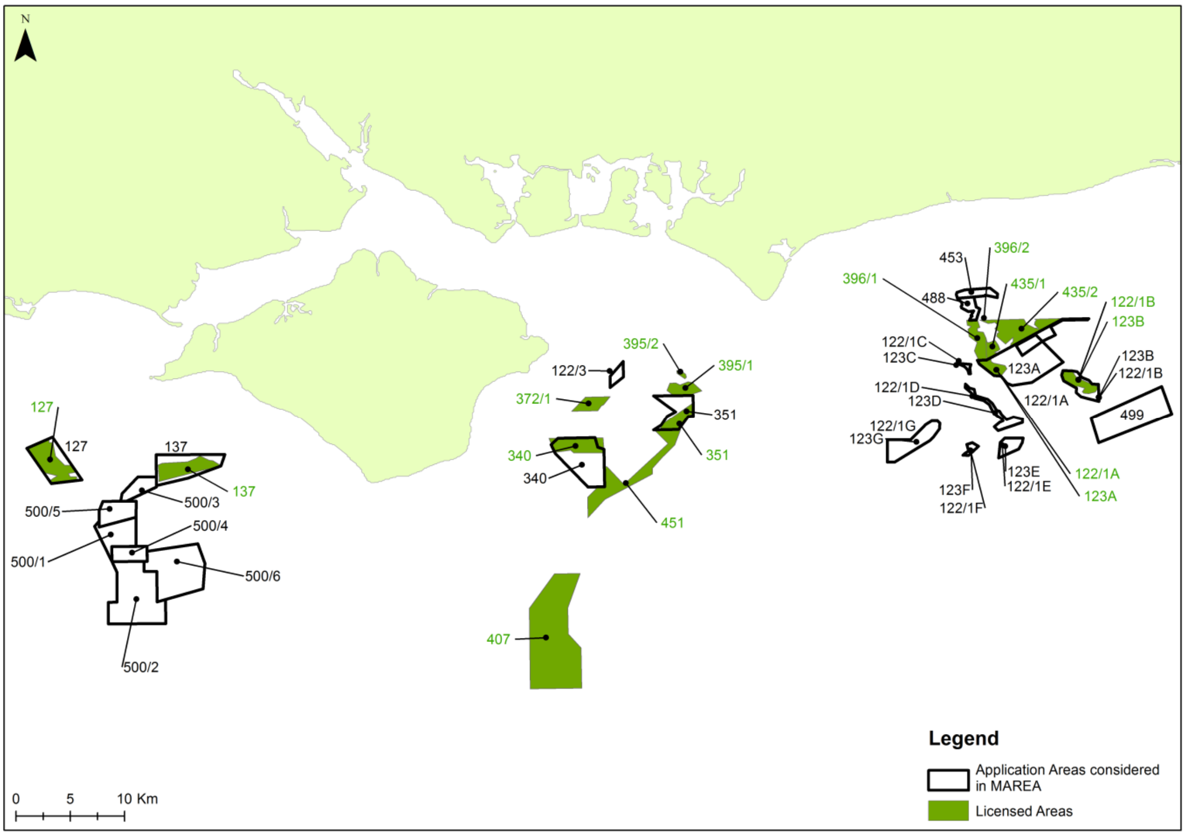


Figure 3.17: South Coast British Geological Survey total combined data layer map.

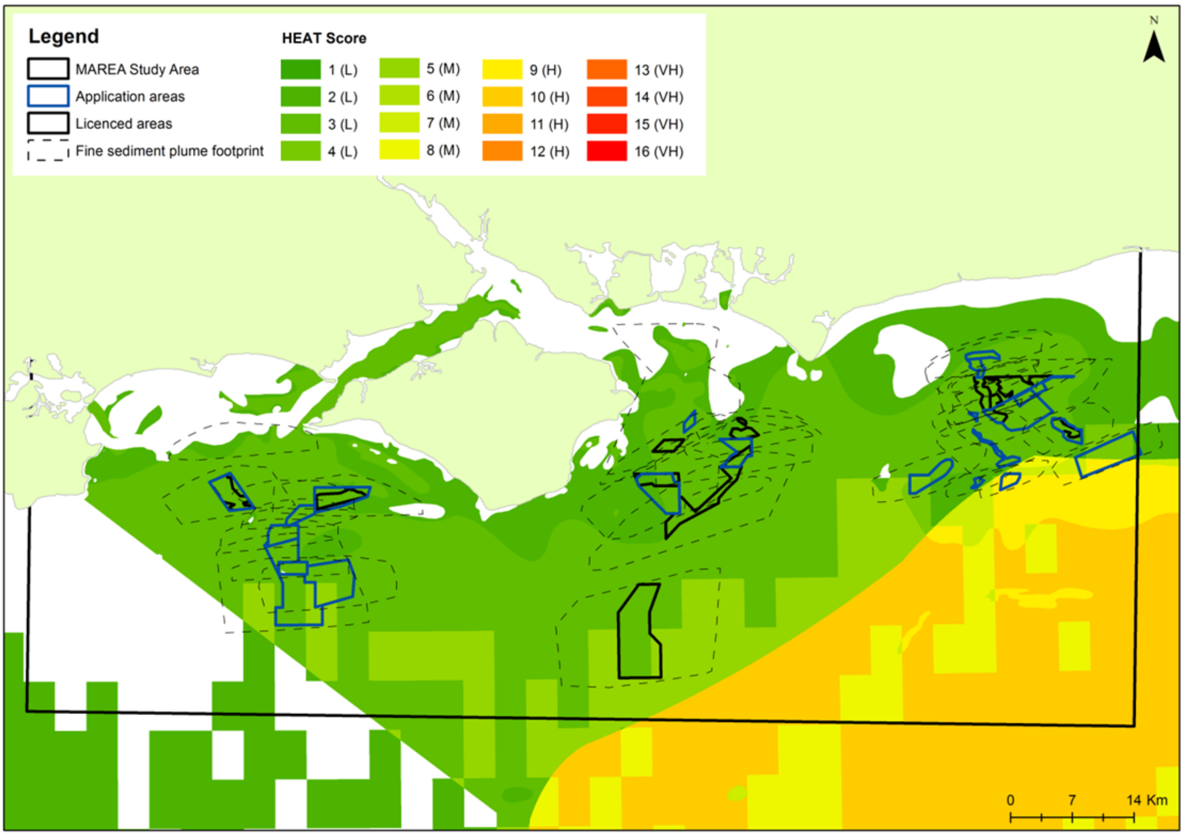


Table 3.7: Screening of South Coast region renewal and application areas.

Area (Status)	Licence Name (Operator)	Impact Zone	Habitat sediment Type: Preferred	Habitat sediment Type: Marginal	Coull *et al.* (1998)	ESFJC	VMS	IHLS		In	Out
453 (Application)	**Owers Extension** (CEMEX UK Marine Ltd)	PIZ	✓	✓						In	
		SIZ	✓	✓						In	
453 (Application)	**Inner Owers North** (Lafarge Tarmac Marine Ltd)	PIZ	✓	✓						In	
		SIZ	✓	✓						In	
434 (500/3) (Application)	**South of Needles Channel** (Lafarge Tarmac Marine Ltd)	PIZ	✓							In	
		SIZ	✓	✓						In	

465/1 (500/5) (Application)	**West Channel** (Hanson Aggregates Marine Ltd)	PIZ	✓						In	
		SIZ	✓	✓					In	
465/2 (500/6) (Application)	**West Channel** (Hanson Aggregates Marine Ltd)	PIZ	✓				✓		In	
		SIZ	✓	✓			✓		In	
437 (500/4) (Application)	**South West Isle of Wight** (Lafarge Tarmac Marine Ltd)	PIZ	✓						In	
		SIZ	✓	✓					In	
500/1 (Application)	**South Wight** (Hanson Aggregates Marine Ltd)	PIZ	✓						In	
		SIZ	✓	✓					In	
500/2 (Application)	**South Wight** (Hanson Aggregates Marine Ltd)	PIZ	✓				✓		In	
		SIZ	✓	✓			✓		In	
500/1 (Application)	**South Wight** (Lafarge Tarmac Marine Dredging Ltd)	PIZ	✓						In	
		SIZ	✓	✓					In	
500/2 (Application)	**South Wight** (Lafarge Tarmac Marine Ltd)	PIZ	✓				✓		In	
		SIZ	✓	✓			✓		In	
340 (Application - Renewal)	**South East Isle of Wight** (CEMEX UK Marine Ltd)	PIZ	✓	✓					In	
		SIZ	✓	✓				✓	In	
340 (Application - Renewal)	**South East Isle of Wight** (Volker Dredging Ltd)	PIZ	✓	✓					In	
		SIZ	✓	✓				✓	In	
137 (Application – Renewal)	**Needles Isle of Wight** (CEMEX UK Marine Ltd)	PIZ	✓	✓					In	
		SIZ	✓	✓					In	
407 (Application – Renewal)	**St Catherine's** (CEMEX UK Marine Ltd)	PIZ	✓				✓	✓	In	
		SIZ	✓				✓	✓	In	
499 (Pre-Application)	**Outer Owers** (Hanson Aggregates Marine Ltd)	PIZ		✓			✓	✓	In	
		SIZ		✓			✓	✓	In	
351 (Application – Renewal)	**South East Isle of Wight** (Northwood (Fareham) Ltd)	PIZ	✓	✓				✓	In	
		SIZ	✓	✓				✓	In	

351 (Application – Renewal)	**South East Isle of Wight** (Volker Dredging Ltd)	PIZ	✓	✓				✓	In	
		SIZ	✓	✓				✓	In	
451 (Application – Renewal)	**St Catherine's** (Westminster Gravels Ltd)	PIZ	✓	✓				✓	In	
		SIZ	✓	✓				✓	In	
122/1A (Application – Renewal)	**Owers Bank** (Lafarge Tarmac Marine Ltd)	PIZ	✓	✓					In	
		SIZ	✓	✓				✓	In	
122/1C (Application – Renewal)	**Owers Bank** (Lafarge Tarmac Marine Ltd)	PIZ	✓						In	
		SIZ	✓					✓	In	
122/1B (Application – Renewal)	**Owers Bank** (Lafarge Tarmac Marine Ltd)	PIZ	✓	✓					In	
		SIZ	✓	✓			✓		In	
122/1D (Application – Renewal)	**Owers Bank** (Lafarge Tarmac Marine Ltd)	PIZ	✓	✓				✓	In	
		SIZ	✓	✓				✓	In	
122/1G (Application – Renewal)	**Owers Bank** (Lafarge Tarmac Marine Ltd)	PIZ	✓	✓			✓	✓	In	
		SIZ	✓	✓			✓	✓	In	
122/1E (Application – Renewal)	**Owers Bank** (Lafarge Tarmac Marine Dredging Ltd)	PIZ		✓			✓	✓	In	
		SIZ		✓			✓	✓	In	
122/1F (Application – Renewal)	**Owers Bank** (Lafarge Tarmac Marine Ltd)	PIZ		✓				✓	In	
		SIZ		✓			✓	✓	In	
123G (Application – Renewal)	**Owers Bank** (CEMEX UK Marine Ltd)	PIZ	✓	✓			✓	✓	In	
		SIZ	✓	✓			✓	✓	In	
123F (Application – Renewal)	**Owers Bank** (CEMEX UK Marine Ltd)	PIZ		✓				✓	In	
		SIZ		✓			✓	✓	In	
123E (Application – Renewal)	**Owers Bank** (CEMEX UK Marine Ltd)	PIZ	✓	✓					In	
		SIZ	✓	✓			✓		In	
123D (Application – Renewal)	**Owers Bank** (CEMEX UK Marine Ltd)	PIZ	✓	✓				✓	In	
		SIZ	✓	✓				✓	In	
123C (Application – Renewal)	**Owers Bank** (CEMEX UK Marine Ltd)	PIZ	✓						In	
		SIZ	✓					✓	In	
123A (Application – Renewal)	**Owers Bank** (CEMEX UK Marine Ltd)	PIZ	✓	✓					In	
		SIZ	✓	✓				✓	In	

123B (Application – Renewal)	**Owers Bank** (CEMEX UK Marine Ltd)	PIZ	✓	✓					In	
		SIZ	✓	✓			✓		In	
122/3 (Application – Renewal)	**East Isle of Wight / North Nab** (Lafarge Tarmac Marine Ltd)	PIZ	✓						In	
		SIZ	✓	✓					In	
127 (Application – Renewal)	**South West Isle of Wight** (Hanson Aggregates Marine Ltd)	PIZ	✓						In	
		SIZ	✓						In	
127 (Application – Renewal)	**South West Isle of Wight** (Lafarge Tarmac Marine Ltd)	PIZ	✓						In	
		SIZ	✓						In	

Table 3.8: Screening of South Coast region licence areas.

Area (Status)	Licence Name (Operator)	Impact Zone	Habitat sediment Type: Preferred	Habitat sediment Type: Marginal	Coull *et al.* (1998)	ESFJC	VMS	IHLS	In	Out
435/2 (Licence)	**Inner Owers** (CEMEX UK Marine Ltd)	PIZ	✓						In	
		SIZ	✓						In	
396/1 (Licence)	**Inner Owers** (Lafarge Tarmac Marine Ltd)	PIZ	✓						In	
		SIZ	✓						In	
396/2 (Licence)	**Inner Owers** (Lafarge Tarmac Marine Ltd)	PIZ	✓						In	
		SIZ	✓						In	
122/1A (Licence)	**Owers Bank** (Lafarge Tarmac Marine Ltd)	PIZ	✓						In	
		SIZ	✓					✓	In	
435/1 (Licence)	**Inner Owers** (Hanson Aggregates Marine Ltd)	PIZ	✓						In	
		SIZ	✓						In	
395/2 (Licence)	**Off Selsey Bill** (Kendall Bros (Portsmouth) Ltd)	PIZ	✓	✓					In	
		SIZ	✓	✓					In	

122/1B (Licence)	**Owers Bank** (Lafarge Tarmac Marine Ltd)	PIZ	✓						In	
		SIZ	✓				✓		In	
395/1 (Licence)	**Off Selsey Bill** (Kendall Bros (Portsmouth) Ltd)	PIZ	✓	✓					In	
		SIZ	✓	✓				✓	In	
351 (Licence)	**South East Isle of Wight** (Volker Dredging Ltd)	PIZ	✓					✓	In	
		SIZ	✓					✓	In	
372/1 (Licence)	**North Nab** (Hanson Aggregates Marine Ltd)	PIZ	✓						In	
		SIZ	✓	✓					In	
451/2 (Licence)	**St Catherine's** (Westminster Gravels Ltd)	PIZ	✓					✓	In	
		SIZ	✓	✓				✓	In	
127 (Licence)	**South West Needles** (Hanson Aggregates Marine Ltd)	PIZ	✓						In	
		SIZ	✓						In	
340 (Licence)	**Nab** (CEMEX UK Marine Ltd)	PIZ	✓	✓					In	
		SIZ	✓	✓				✓	In	
137 (Licence)	**Area A** (CEMEX UK Marine Ltd)	PIZ	✓	✓					In	
		SIZ	✓	✓					In	
451/1 (Licence)	**St Catherine's** (Westminster Gravels Ltd)	PIZ	✓					✓	In	
		SIZ	✓	✓				✓	In	
127 (Licence)	**South West Needles** (Lafarge Tarmac Marine Ltd)	PIZ	✓						In	
		SIZ	✓						In	
351 (Licence)	**South East Isle of Wight** (Northwood (Fareham) Ltd)	PIZ	✓					✓	In	
		SIZ	✓					✓	In	
395/1 (Licence)	**Off Selsey Bill** (Lafarge Tarmac Marine Ltd)	PIZ	✓	✓					In	
		SIZ	✓	✓				✓	In	
395/2 (Licence)	**Off Selsey Bill** (Lafarge Tarmac Marine Ltd)	PIZ	✓	✓					In	
		SIZ	✓	✓					In	
123A (Licence)	**Owers Bank** (CEMEX UK Marine Ltd)	PIZ	✓						In	
		SIZ	✓					✓	In	

123B (Licence)	**Owers Bank** (CEMEX UK Marine Ltd)	PIZ	✓						In	
		SIZ	✓				✓		In	
340 (Licence)	**Nab** (Volker Dredging Ltd)	PIZ	✓	✓					In	
		SIZ	✓	✓				✓	In	

4. Stage 2 Results

Stage 2 of the process involves the production of a CIA for each of the MAREA regions, using the MAREA region boundaries and the respective MAREA impact assessment protocols and methodologies (EMU Ltd, 2012a, 2012b; ERM Ltd, 2010, 2012; Appendices H-K). All the existing licence areas and application areas that have been screened in at the end of Stage 1 contribute to the cumulative effect footprint. Further there may be in-combination effects with other seabed user industries with the same environmental effect exposure pathways and footprints.

Stage 2 maps the effect footprints of all known and foreseeable activities (plans or projects) and assesses the levels of spatial interaction with Atlantic Herring potential spawning habitat. It is important to note that in establishing these footprints a worst case approach has been followed, resulting in what the EIA WG believes to be the maximum footprints of interaction. The rationale for this process allows the regional CIAs, regarding the characterisation of Atlantic Herring potential spawning habitat and subsequent impact assessment, to act as supplements to each of the MAREAs.

The following sub-sections provide a summary of the conclusions of the CIAs for each region, with the full reports appended as Appendices H-K.

4.1. Regional Cumulative Impact Assessment

In order to assess the cumulative impacts of marine aggregate extraction on Atlantic Herring spawning habitat it is necessary to consider the impacts within the PIZ, i.e. direct impacts, and indirect impacts within the SIZ (Reach *et al.*, 2013). Dredging effects within the PIZ will potentially have a detrimental impact on Atlantic Herring spawning through the direct removal of eggs during the spawning period, direct removal of suitable habitat, and alteration of spawning habitat.

Indirect effects within the SIZ may potentially have an impact on Atlantic Herring spawning through the sediment plume generated during dredging smothering eggs and changing the sediment composition over time to a composition that is finer and therefore less suitable for spawning. The ability of the seabed within the PIZ and SIZ to recover will also be considered.

4.1.1. Humber Region

This section summarises the results of a CIA for the Humber MAREA region, and which is presented in full as Appendix H. The aggregate licence areas (PIZ) within the Humber MAREA region cumulatively overlap with 0.0 km^2 of very high 'heat' class, 36.3 km^2 of high 'heat' class, 215.0 km^2 of medium 'heat' class, and 187.6 km^2 of low 'heat' class. When these areas are then considered against the spatial extent of other anthropogenic pressures in the region, the analysis also shows that 29.6 km^2 of high 'heat' class, 84.5 km^2 of medium 'heat' class and 68.6 km^2 of low 'heat' class is subjected only to direct pressure from dredging activity. Within the MAREA boundary there is approximately 2,202 km^2 of high 'heat' class, 3,417 km^2 of medium 'heat' class and 2,468 km^2 of low 'heat' class. Therefore, 1.3% of the total available high 'heat' class, 2.5% of the medium 'heat' class, and 2.8% of the low 'heat' class within the Humber MAREA boundary is impacted solely by dredging activity (PIZ).

The direct removal of eggs within the PIZs of the Humber region is assessed to be a **small** magnitude effect due to the site-specific extent of dredging (i.e. the seabed actually dredged during a spawning event will be much smaller than the full licence areas considered in this assessment), and the short-term duration and occasional frequency of the effect. Within the Humber MAREA boundary Atlantic Herring are assessed as having a medium-low tolerance to removal of eggs because the removal of eggs during dredging results in mortality and may have a detrimental effect on recruitment. The adaptability of Atlantic Herring to this effect is low, however the recoverability is high because the majority of potential spawning habitat within the MAREA region lies outside of the aggregate licence areas and Atlantic Herring are therefore expected to deposit much greater numbers of eggs outside of the licence areas than within. Based upon the tolerance, adaptability and recoverability, the sensitivity of Atlantic Herring to egg removal is assessed as **high**. **The cumulative impact of direct removal of eggs during dredging within the Humber MAREA region is assessed as moderate significance**.

The direct removal of potential spawning sediment by dredging is considered to be site-specific in extent because it only occurs within the PIZ, short-term in duration, and intermittent in frequency. Because the aggregate industry is required to leave a layer of sediment at the cessation of dredging similar to that which existed before dredging commenced, it is assessed as being of **low** magnitude. Atlantic Herring in the Humber MAREA region are assessed as having a medium tolerance and adaptability to the removal of the available potential spawning sediment and a high recoverability because they will be able to spawn on other areas of suitable spawning sediment elsewhere within the MAREA region. Taking into account the tolerance, adaptability and recoverability the overall sensitivity of Atlantic Herring to removal of potential spawning sediment is assessed as **medium**. **The cumulative impact of direct removal of suitable spawning habitat within the Humber MAREA region is assessed as minor significance**.

Physical contact of the draghead with the seabed can also result in fining of the Atlantic Herring potential spawning habitat within the PIZ. The magnitude of effect of alteration of PIZ habitat is **small-medium** because the effect in the Humber MAREA region is assessed as site-specific, medium-term in duration and occasional in frequency. Atlantic Herring have a low tolerance; and a medium adaptability and recoverability to the alteration of habitat because the entire PIZ will not become unavailable for spawning and they will be able to spawn on other areas of potential spawning sediment elsewhere within the MAREA region. The overall sensitivity of Atlantic Herring to alteration of PIZ habitat is assessed as **medium**. **The cumulative impact of direct alteration of PIZ habitat within the Humber MAREA region is assessed as minor significance**.

Smothering of eggs in the wider SIZ, through deposition of sediment onto the seabed, is assessed as a **small** magnitude effect because it has a localised extent, is short-term in its duration and occasional in frequency. Atlantic Herring in the Humber MAREA region are assessed as having medium tolerance and a low-medium adaptability to smothering. The degree of recoverability is assessed as medium and Atlantic Herring eggs are, therefore, assessed as having a **medium** sensitivity to smothering. Based upon the medium sensitivity and small magnitude of effect, **the overall cumulative impact on Atlantic Herring in the Humber MAREA region from sediment deposition within the SIZ is of minor significance**.

Fining of potential spawning habitat in SIZ may occur as a result of the dredging process, however any changes to sediment particle size as a result of dredging activity are considered to be localised in extent, short-term in duration, and occasional in occurrence. Particle size changes are therefore assessed as being a **small** magnitude effect. Atlantic Herring within the Humber MAREA region are assessed as having a medium tolerance to fining of potential spawning habitat within the SIZ, because of the additional potential habitat within the MAREA region available for spawning. Atlantic Herring are also assessed as having a high adaptability and recoverability to changes in the sediment particle size. The overall sensitivity of Atlantic Herring to fining of potential spawning habitat is considered to be **medium**. **Taking into account the sensitivity and magnitude of effect the cumulative effect of fining of sediment particle size in the Humber MAREA region is assessed to be of minor significance**.

In addition to dredging, there are several other seabed user activities that have the potential to interact with Atlantic Herring potential spawning habitat in the Humber MAREA region; these activities are:

- Offshore renewable arrays (including potential cable corridors);
- Trawl fisheries;
- Dredge fisheries;
- Oil and gas pipelines;
- Power cables and telecommunications; and
- Dredge fines disposal sites.

The potential impacts associated with seabed infrastructure such as offshore renewable arrays, oil and gas pipelines and telecommunications cables are loss of habitat and egg mortality as a result of seabed disturbance during installation. Trawl and dredge fisheries actively target the seabed and as a result the potential impacts on Atlantic Herring potential spawning habitat from both types of fishing are egg mortality from seabed disturbance. Dredge fisheries may also result in the direct removal of eggs and alteration of habitat structure.

Table 4.1 quantifies the interaction between seabed user activities and 'heat' classes across the MAREA study region, noting the total footprint figures represent all seabed user interaction with 'heat' class, albeit with each sector interacting to a varying degree via different impact pathways. The results show that approximately 1,283 km^2 of high 'heat' class, approximately 1,282 km^2 of medium 'heat' class and approximately 853 km^2 of low 'heat' class lies within the footprint of seabed user activity. This constitutes 58.3%, 37.5%, and 34.5% of the total available Atlantic Herring high, medium and low 'heat' classes in the Humber MAREA region, respectively. The total value indicates that there is a degree of overlap between seabed user activity, with some areas of 'heat' class receiving impacts from more than a single sector i.e. the mobile activities such as dredge or trawl fishing overlap, to some degree, with the footprints of static activities.

Table 4.1 also shows that there are some areas where dredging activity, alone, interacts with 'heat' classes (i.e. there is no overlap with any other activity). Dredging, alone, overlaps with approximately 29.6 km^2 of high 'heat' class, 84.5 km^2 of medium 'heat' class, and 68.6 km^2 of low 'heat' class (Table 4.1). This accounts for 1.3% of the high 'heat' class, 2.5% of medium 'heat' class and 2.8% of the low 'heat' class within the Humber MAREA boundary, respectively. When considering these areas it should be noted that, in some cases, mobile fishing activity actively avoids dredging areas – and when dredging ceases it is likely that these areas will be targeted by fishing activity. It should also be noted that Table 4.1 presents a spatial analysis of the data only. No inferences on the respective significance of user activities are made.

Table 4.1: Footprint of Seabed User Activity on Atlantic Herring 'Heat' Class in the Humber MAREA Region.

Seabed User Activity	Overlap with high 'heat' class (km^2)	% of total available high 'heat' class	Overlap with medium 'heat' class (km^2)	% of total available medium 'heat' class	Overlap with low 'heat' class (km^2)	% of total available low 'heat' class
Operating Windfarm Turbine Footprint	0	0	0.156	0.005	0.129	0.005
Operating Windfarm Licence Areas	0	0	26.939	0.79	8.219	0.33
Under Construction Windfarm Areas	27.179	1.23	199.589	5.84	0.083	0.002
Proposed Windfarms Indic. Turbine Footprint	0.656	0.03	1.276	0.04	0.149	0.006
Windfarm Licence Areas Proposed	283.918	12.89	531.767	15.56	67.285	2.73
Trawl Fishery	774.455	35.17	602.792	17.64	676.301	27.40
Dredge Fishery	558.093	25.35	216.104	6.32	26.359	1.07
Pipelines*	0.1470	0.007	0.2181	0.006	0.1567	0.006
Power Cables*	0.0141	0.001	0.0012	3.5×10^{-5}	0.0054	2.2×10^{-4}
Telecommunications*	0	0	0	0	0.0011	4.5×10^{-5}
Worst Case Proposed Power Cables*	0.0671	0.003	0.0490	0.001	0.0259	0.001
Dredge Fines Disposal Sites	51.860	2.36	34.556	1.01	38.417	1.56
Dredging Activity (PIZ)	36.328	1.65	214.992	6.29	187.579	7.60
TOTAL	**1282.6**	**58.25**	**1281.5**	**37.50**	**852.6**	**34.54**
Dredging Activity (PIZ) ONLY†	29.6	1.34	84.5	2.47	68.6	2.78

* Assumes that entirety of cable or pipeline is surface laid and not buried, and this therefore over represents footprint for these activities. † The area of seabed which has a footprint associated with dredging alone i.e. no overlap with any other activity

4.1.2. Anglian Region

This section summarises the results of a CIA for the Anglian MAREA region, which is presented in full as Appendix I. The aggregate licence areas (PIZ) within the Anglian MAREA region cumulatively overlap with approximately 0.0 km^2 of very high 'heat' class, 0.3 km^2 of high 'heat' class, 61 km^2 of medium 'heat' class, and 139 km^2 of low 'heat' class. When these areas are then considered against the spatial extent of other anthropogenic pressures in the region, the analysis shows that 0.3 km^2 of high 'heat' class, 24.6 km^2 of medium 'heat' class and 179.6 km^2 of low 'heat' class is subjected only to direct pressure from dredging activity. Within the MAREA boundary there is 47.2 km^2 of high 'heat' class, 1,811 km^2 of medium 'heat' class and 1,991 km^2 of low 'heat' class. Therefore, 0.6% of the total available high 'heat' class, 1.4% of the medium 'heat' class, and 9.0% of the low 'heat' class within the Anglian MAREA boundary is impacted solely by dredging activity (PIZ).

The direct removal of eggs within the PIZs of the Anglian region is assessed to be a **very low** magnitude effect due to its site specific extent, its temporary duration and occasional frequency. Within the Anglian MAREA boundary Atlantic Herring are assessed as having a medium tolerance to removal of eggs because the removal of eggs during dredging results in mortality and may have a detrimental effect on recruitment. The adaptability of Atlantic Herring to this effect is low, however the recoverability is high because the majority of spawning habitat within the MAREA region lies outside of the aggregate licence areas and Atlantic Herring are therefore expected to deposit much greater numbers of eggs outside of the licence areas than within. Based upon the tolerance, adaptability and recoverability, the sensitivity of Atlantic Herring to egg removal is assessed as **medium**. **The cumulative impact of direct removal of eggs during dredging within the Anglian MAREA region is assessed as not significant**.

The direct removal of potential spawning sediment by dredging within the Anglian MAREA region is considered to be site-specific in extent because it only occurs within the PIZ, medium-term in duration, and rare in frequency. Because the aggregate industry is required to leave a layer of sediment at the cessation of dredging similar to that which existed before dredging commenced, it is assessed as being of **low** magnitude. Atlantic Herring in the Anglian MAREA region are assessed as having a medium tolerance and adaptability to the removal of the available potential spawning sediment and a high recoverability because they will be able to spawn on other areas of potential spawning sediment elsewhere within the MAREA region. Taking into account the tolerance, adaptability and recoverability the overall sensitivity of Atlantic Herring to removal of potential spawning sediment is assessed as **medium**. **The cumulative impact of direct removal of suitable spawning habitat within the Anglian MAREA region is assessed as minor significance**.

Physical contact of the draghead with the seabed can also result in fining of the Atlantic Herring potential spawning habitat within the PIZ. The magnitude of effect of alteration of PIZ habitat within the Anglian MAREA region is **medium** because the effect is site-specific, potentially long-term in duration and occasional in frequency. Atlantic Herring in the Anglian region are assessed as having a medium tolerance to the effect; as well as a high adaptability and recoverability because the entire PIZ will not become unavailable for spawning and they will be able to spawn on other areas of potential spawning sediment elsewhere within the MAREA region. The overall sensitivity of Atlantic Herring to alteration of PIZ habitat is assessed as **low**. **The cumulative impact of direct alteration of PIZ habitat within the Anglian MAREA region is assessed as minor significance**.

Smothering of eggs in the wider SIZ through deposition of sediment onto the seabed is assessed as a **very low** magnitude effect, because it has a site-specific extent, is temporary in its duration and occasional in frequency. Atlantic Herring in the Anglian MAREA region are assessed as having medium tolerance to smothering. Their overall adaptability is assessed as medium and recoverability is high. Atlantic Herring eggs are assessed as having a **medium** sensitivity to smothering. Eggs are only present on the seabed during the spawning period, with each egg hatching within 2 weeks (Stratoudakis *et al.*, 1998) and eggs present for a period of 4 to 5 weeks. The overall degree of interaction between sediment deposition and smothering of eggs is considered small and based upon the medium sensitivity and very low magnitude of effect, **the overall cumulative impact on Atlantic Herring in the Anglian MAREA region from sediment deposition within the SIZ is not significant**.

Fining of potential spawning habitat in SIZ may occur as a result of the dredging process, however any changes to sediment particle size as a result of dredging activity are considered to be site-specific in extent, temporary in duration, and occasional in occurrence. Particle size changes are therefore assessed as being a **very low** magnitude effect. Atlantic Herring have a medium tolerance and recoverability to fining of potential spawning habitat within the SIZ because of the additional potential habitat within the MAREA region available for spawning. Atlantic Herring are also expected to have a low adaptability to changes in the sediment particle size. The overall sensitivity of Atlantic Herring to fining of potential spawning habitat is considered to be **medium**. **Taking into account the sensitivity and magnitude of effect the cumulative effect of fining of sediment particle size in the SIZs in the Anglian MAREA region is assessed to be not significant**.

In addition to dredging, there are several other seabed user activities that have the potential to interact with Atlantic Herring potential spawning habitat in the Anglian MAREA region; these activities are:

- Offshore renewable arrays;
- Trawl fisheries;
- Dredge fisheries;
- Oil and gas pipelines;
- Power and telecommunication cables; and
- Dredge fines disposal sites.

The potential impacts associated with seabed infrastructure such as offshore renewable arrays, oil and gas pipelines and telecommunications cables are loss of habitat and egg mortality as a result of seabed disturbance during installation. Trawl and dredge fisheries actively target the seabed and as a result the potential impacts on Atlantic Herring potential spawning habitat from both types of fishing are egg mortality from seabed disturbance. Dredge fisheries may also result in the direct removal of eggs and alteration of habitat structure.

Table 4.2 quantifies the interaction between seabed user activities and ‘heat’ classes across the MAREA study region, noting the total footprint figures represent all seabed user interaction with potential spawning habitat, albeit with each sector interacting to a varying degree via different impact pathways. The results show that approximately 15 km^2 of high ‘heat’ class, 1,576 km^2 of medium ‘heat’ class, and 1,093 km^2 of low ‘heat’ class lies within the footprint of seabed user activity. This constitutes 32.4%, 87.0%, and 54.9% of the total available Atlantic Herring high, medium and low 'heat' classes in the Anglian MAREA region, respectively. The total value indicates that there is a degree of overlap between seabed user activity, with some areas of 'heat' class receiving impacts from more than a single sector i.e. the mobile activities such as dredge or trawl fishing overlap, to some degree, with the footprints of static activities.

Table 4.2 also shows that there are some areas where dredging activity, alone, interacts with 'heat' classes (i.e. there is no overlap with any other activity). Dredging, alone, overlaps with approximately 0.3 km^2 of high 'heat' class, 24.6 km^2 of medium 'heat' class, and 179.6 km^2 of low 'heat' class (Table 4.2). This accounts for 0.6% of high 'heat' class, 1.4% of medium 'heat' class, and 9.0% of low 'heat' class within the Anglian MAREA boundary, respectively. When considering these areas it should be noted that, in some cases, mobile fishing activity actively avoids dredging areas – and when dredging ceases it is likely that these areas will be targeted by fishing activity. It should also be noted that Table 4.2 presents a spatial analysis of the data only. No inferences on the respective significance of user activities are made.

Table 4.2: Footprint of Seabed User Activity on Atlantic Herring 'Heat' Class in the Anglian MAREA Region.

Seabed User Activity	Overlap with high 'heat' class (km^2)	% of total available high 'heat' class	Overlap with medium 'heat' class (km^2)	% of total available medium 'heat' class	Overlap with low 'heat' class (km^2)	% of total available low 'heat' class
Operating Windfarm Turbine Footprint	0	0	0.024	0.001	0.045	0.002
Operating Windfarm Licence Areas	0	0	2.450	0.135	6.451	0.323
Under Construction Windfarm Areas	0	0	0	0	0	0
Proposed Windfarms Indic. Turbine Footprint	0.027	0.06	2.348	0.129	0.795	0.039
Windfarm Licence Areas Proposed	14.879	31.55	984.981	54.40	328.101	16.48
Trawl Fishery	14.879	31.55	1397.103	77.16	645.166	32.40
Dredge Fishery	0	0	0	0	0	0
Pipelines*	0	0	0.029	0.002	0.165	0.008
Power Cables*	0	0	0.0004	2.2×10^{-5}	0.0061	0.0003
Telecommunications*	0	0	0.0148	0.0008	0.0095	0.0005

Seabed User Activity	Overlap with high 'heat' class (km^2)	% of total available high 'heat' class	Overlap with medium 'heat' class (km²)	% of total available medium 'heat' class	Overlap with low 'heat' class (km²)	% of total available low 'heat' class
Worst Case Proposed Power Cables*	0	0	0.0260	0.0014	0.0092	0.0005
Dredge Fines Disposal Sites	0	0	346.867	19.16	5.758	0.29
Dredging Activity (PIZ)	0.34	0.73	61.330	3.39	139.291	6.99
TOTAL	**15.3**	**32.42**	**1575.6**	**87.01**	**1092.7**	**54.87**
Dredging Activity (PIZ) ONLY†	0.30	0.64	24.61	1.36	179.62	9.01

* Assumes that entirety of cable or pipeline is surface laid and not buried, and this therefore over represents footprint for these activities. † The area of seabed which has a footprint associated with dredging alone i.e. no overlap with any other activity

4.1.3. Outer Thames Estuary Region

This section summarises the results of a CIA for the Outer Thames Estuary MAREA region, and which is presented in full as Appendix J. The aggregate licence areas (PIZ) within the Outer Thames MAREA region cumulatively overlap with 0.0 km^2 of very high 'heat' class, 0.7 km^2 of high 'heat' class, 98.6 km^2 of medium 'heat' class, and 59.7 km^2 of low 'heat' class. When these areas are then considered against the spatial extent of other anthropogenic pressures in the region, the analysis shows that 0.7 km^2 of high 'heat' class, 7.9 km^2 of medium 'heat' class and 3.0 km^2 of low 'heat' class is subjected only to direct pressure from dredging activity. Within the MAREA boundary there is 326 km^2 of high 'heat' class, 2,969 km^2 of medium 'heat' class and 797 km^2 of low 'heat' class. Therefore, 0.2% of the total available high 'heat' class, 0.3% of the medium 'heat' class, and 0.4% of the low 'heat' class within the Outer Thames MAREA boundary is impacted solely by dredging activity (PIZ).

The direct removal of eggs within the PIZs of the Outer Thames region is assessed to be a **small** magnitude effect due to its site-specific extent (i.e. the seabed actually dredged during a spawning event will be much smaller than the licence areas), its temporary duration and occasional frequency. Within the Outer Thames MAREA boundary Atlantic Herring are assessed as having a medium tolerance to removal of eggs because the removal of eggs during dredging results in mortality and may have a detrimental effect on recruitment. The adaptability of Atlantic Herring to this effect is low, however the recoverability is high because the majority of spawning habitat within the MAREA region lies outside of the aggregate licence areas and Atlantic Herring are therefore expected to deposit much greater numbers of eggs outside of the licence areas than within. Based upon the tolerance, adaptability and recoverability, the sensitivity of Atlantic Herring to egg removal is assessed as **medium**. **The cumulative impact of direct removal of eggs during dredging within the Outer Thames MAREA region is assessed as minor to moderate significance**.

The direct removal of potential spawning sediment by dredging is considered to be site-specific in extent because it only occurs within the PIZ, short-term in duration, and intermittent in frequency.

Without mitigation the complete removal of the potential spawning sediment within the cumulative PIZ footprint within the Outer Thames would be considered a high magnitude effect, but because the aggregate industry is required to leave a layer of sediment at the cessation of dredging similar to that which existed before dredging commenced, it is assessed as being of **low - medium** magnitude. Atlantic Herring in the Outer Thames MAREA region are assessed as having a medium tolerance and adaptability to the removal of the available potential spawning sediment and a high recoverability because they will be able to spawn on other areas of potential spawning sediment elsewhere within the MAREA region. Taking into account the tolerance, adaptability and recoverability the overall sensitivity of Atlantic Herring to removal of potential spawning sediment is assessed as **medium**. **The cumulative impact of direct removal of suitable spawning habitat within the Outer Thames MAREA region is assessed as moderate significance**.

Physical contact of the draghead with the seabed can also result in fining of the Atlantic Herring potential spawning habitat within the PIZ. The magnitude of effect of alteration of PIZ habitat is **small-medium** because the effect is site-specific, short-term in duration and intermittent in frequency. Atlantic Herring have a medium tolerance and adaptability to the effect; as well as a high recoverability because the entire PIZ will not become unavailable for spawning and they will be able to spawn on other areas of potential spawning sediment elsewhere within the MAREA region. The overall sensitivity of Atlantic Herring to alteration of PIZ habitat is assessed as **medium**. **The cumulative impact of direct alteration of PIZ habitat within the Outer Thames MAREA region is assessed as moderate significance**.

Smothering of eggs in the wider SIZ through deposition of sediment onto the seabed is assessed as a **small** magnitude effect, because it has a localised extent, is short-term in its duration and occasional in frequency. Atlantic Herring in the Outer Thames MAREA region are assessed as having medium tolerance and adaptability to smothering; however, the degree of recoverability varies from low to high with distance from the PIZ boundary. The overall recoverability is therefore assessed as medium and Atlantic Herring eggs are assessed as having a **medium** sensitivity to smothering. Eggs are only present on the seabed during the spawning period, with each egg hatching within 2 weeks (Stratoudakis *et al.*, 1998) and eggs present for a period of 4 to 5 weeks. The overall degree of interaction between sediment deposition and smothering of eggs is considered small and based upon the medium sensitivity and small magnitude of effect, **the overall cumulative impact on Atlantic Herring in the Outer Thames MAREA region from sediment deposition within the SIZ is minor significance**.

Fining of suitable habitat in SIZ may occur as a result of the dredging process, however any changes to sediment particle size as a result of dredging activity are considered to be localised in extent, short-term in duration, and occasional in occurrence. Particle size changes are therefore assessed as being a **small** magnitude effect. Atlantic Herring have a medium tolerance and recoverability to fining of potential habitat within the SIZ because of the additional potential habitat within the MAREA region available for spawning. Atlantic Herring are also expected to have a medium recoverability to changes in the sediment particle size because any reduced recruitment of stock is expected to recover within the medium-term (<10 years). The overall sensitivity of Atlantic Herring to fining of potential spawning habitat is considered to be **medium**. **Taking into account the**

sensitivity and magnitude of effect the cumulative effect of fining of sediment particle size in the Outer Thames MAREA region is assessed to be minor significance.

In addition to dredging, there are several other seabed user activities that have the potential to interact with Atlantic Herring potential spawning habitat in the Outer Thames Estuary; these activities are:

- Offshore renewable arrays;
- Trawl fisheries;
- Dredge fisheries;
- Oil and gas pipelines;
- Power and telecommunication cables; and
- Dredge fines disposal sites.

The potential impacts associated with seabed infrastructure such as offshore renewable arrays, oil and gas pipelines and telecommunications cables are loss of habitat and egg mortality as a result of seabed disturbance during installation. Trawl and dredge fisheries actively target the seabed and as a result the potential impacts on potential Atlantic Herring potential spawning habitat from both types of fishing are egg mortality from seabed disturbance. Dredge fisheries may also result in the direct removal of eggs and alteration of habitat structure.

Table 4.3 quantifies the interaction between seabed user activities and 'heat' classes across the MAREA study region, noting the total footprint figures represent all seabed user interaction with 'heat' class, albeit with each sector interacting to a varying degree via different impact pathways. The results show that approximately 175 km^2 of high 'heat' class, approximately 2,483 km^2 of medium 'heat' class and approximately 565 km^2 of low 'heat' class lies within the footprint of seabed user activity. This constitutes 53.7%, 83.6%, and 70.9% of the total available Atlantic Herring high, medium and low 'heat' classes in the Outer Thames MAREA region, respectively. The total value indicates that there is a degree of overlap between seabed user activity, with some areas of 'heat' class receiving impacts from more than a single sector i.e. the mobile activities such as dredge or trawl fishing overlap, to some degree, with the footprints of static activities.

Table 4.3 also shows that there are some areas where dredging activity, alone, interacts with 'heat' classes (i.e. there is no overlap with any other activity). Dredging, alone, overlaps with approximately 0.7 km^2 of high 'heat' class, 7.9 km^2 of medium 'heat' class, and 3.0 km^2 of low 'heat' class (Table 4.3). This accounts for 0.2% of high 'heat' class, 0.3% of medium 'heat' class and 0.4% of low 'heat' class within the Outer Thames Estuary MAREA boundary, respectively. It should be noted that Table 4.3 presents a spatial analysis of the data only. No inferences on the respective significance of user activities are made.

Table 4.3: Footprint of Seabed User Activity on Atlantic Herring 'Heat' Class in the Outer Thames MAREA Region.

Seabed User Activity	Overlap with high 'heat' class (km^2)	% of total available high 'heat' class	Overlap with medium 'heat' class (km^2)	% of total available medium 'heat' class	Overlap with low 'heat' class (km^2)	% of total available low 'heat' class
Operating Windfarm Turbine Footprint	0.07	0.020	0.53	0.02	0.002	0.0003
Operating Windfarm Licence Areas	0	0	16.39	0.55	0	0
Under Construction Windfarm Areas	27.18	8.34	199.59	6.72	0.08	0.01
Proposed Windfarms Indic. Turbine Footprint	0.11	0.03	1.20	0.04	0.004	0.0005
Windfarm Licence Areas Proposed	42.44	13.02	514.22	17.32	0.97	0.12
Trawl Fishery	91.22	27.98	2284.49	76.95	560.46	70.32
Dredge Fishery	0	0	0	0	0	0
Pipelines*	0	0	0.0021	7.0×10^{-5}	0.0019	0.0002
Power Cables*	0.0071	0.0022	0.0166	0.0006	0.0085	0.0011
Telecommunications*	0.0015	0.0005	0.0123	0.0005	0.0032	0.0004
Worst Case Proposed Power Cables*	0	0	0.0202	0.0007	0.0098	0.0012
Dredge Fines Disposal Sites	14.40	4.42	671.47	22.62	34.56	4.34
Dredging Activity (PIZ)	0.67	0.21	98.62	3.32	59.69	7.49
TOTAL	**175.2**	**53.74**	**2482.5**	**83.61**	**564.9**	**70.88**
Dredging Activity (PIZ) ONLY†	0.67	0.21	7.94	0.27	3.04	0.38

* Assumes that entirety of cable or pipeline is surface laid and not buried, and this therefore over represents footprint for these activities. † The area of seabed which has a footprint associated with dredging alone i.e. no overlap with any other activity

4.1.4. South Coast Region

This section summarises the results of a CIA for the South Coast MAREA region, and which is presented in full as Appendix K. The aggregate licence areas (PIZ) within the South Coast MAREA region cumulatively overlap with 0.0 km^2 of very high 'heat' class, 11.4 km^2 of high 'heat' class, 28.8 km^2 of medium 'heat' class, and 306.2 km^2 of low 'heat' class. When these areas are then considered against the spatial extent of other anthropogenic pressures in the region, the analysis shows that no high or medium 'heat' class is subjected only to direct pressure from dredging activity, while 90.5 km^2 of low 'heat' class is subjected only to direct pressure from dredging activity. Within the MAREA boundary there is 772 km^2 of high 'heat' class, 706 km^2 of medium 'heat' class and 2,635 km^2 of low 'heat' class. Therefore, none of the total available high and medium 'heat' class is impacted solely by dredging activity (PIZ), while 3.4% of the low 'heat' class within the South Coast MAREA boundary is impacted solely by dredging activity (PIZ).

The direct removal of eggs within the PIZs of the South Coast region is assessed to be a **medium** magnitude effect due to its site-specific extent (i.e. the seabed actually dredged during a spawning event will be much smaller than the licence area), its short-term duration and routine frequency. Within the South Coast MAREA boundary Atlantic Herring are assessed as having a medium tolerance to removal of eggs because the removal of eggs during dredging results in mortality and may have a detrimental effect on recruitment. The adaptability of Atlantic Herring to this effect is low, however the recoverability is high as the change to population is anticipated to be relatively small. Based upon the tolerance, adaptability and recoverability, the sensitivity of Atlantic Herring to egg removal is assessed as **low**. **The cumulative impact of direct removal of eggs during dredging within the South Coast MAREA region is assessed as not significant**.

The direct removal of potential spawning sediment by dredging is considered to be site-specific in extent because it only occurs within the PIZ, medium term in duration, and routine in frequency. It is assessed as being of **medium** magnitude. Atlantic Herring in the South Coast MAREA region are assessed as having a low tolerance and adaptability to the removal of the available potential spawning sediment and a high recoverability because they will be able to spawn on other areas of potential spawning sediment elsewhere within the MAREA region. Taking into account the tolerance, adaptability and recoverability the overall sensitivity of Atlantic Herring to removal of potential spawning sediment is assessed as **medium-high**. **The cumulative impact of direct removal of suitable spawning habitat within the South Coast MAREA region is assessed as minor significance**.

Physical contact of the draghead with the seabed can also result in fining of the Atlantic Herring potential spawning habitat within the PIZ. The magnitude of effect of alteration of PIZ habitat is **low** because the effect is site specific, medium-term in duration and routine in frequency. Atlantic Herring have a medium tolerance, adaptability and recoverability to the effect as they will be able to spawn on other areas of suitable spawning sediment elsewhere within the MAREA region. The overall sensitivity of Atlantic Herring to alteration of PIZ habitat is assessed as **medium**. **The cumulative impact of direct alteration of PIZ habitat within the South Coast MAREA region is assessed as minor significance**.

Smothering of eggs in the wider SIZ through deposition of sediment onto the seabed is assessed as a **medium** magnitude effect, because it has a localised extent, is short-term in its duration and routine in frequency. Atlantic Herring in the South Coast MAREA region are assessed as having low tolerance and medium adaptability to smothering; the recoverability is assessed as medium. Atlantic Herring eggs within the South Coast MAREA region are, therefore, assessed as having a **medium** sensitivity to smothering. **The overall cumulative impact on Atlantic Herring in the South Coast MAREA region from sediment deposition within the SIZ is of minor significance**.

Fining of potential spawning habitat in SIZ may occur as a result of the dredging process, however any changes to sediment particle size as a result of dredging activity are considered to be localised in extent, short-term in duration, and routine in occurrence. Particle size changes are therefore assessed as being a **medium** magnitude effect. Atlantic Herring in the South Coast MAREA region are assessed as having a low tolerance, but a medium adaptability and recoverability to fining of potential habitat within the SIZ because of the additional potential habitat within the MAREA region available for spawning. The overall sensitivity of Atlantic Herring to fining of potential spawning habitat is considered to be **medium**. **Taking into account the sensitivity and magnitude of effect the cumulative effect of fining of sediment particle size in the South Coast MAREA region is assessed to be minor significance**.

In addition to dredging, there are several other seabed user activities that have the potential to interact with Atlantic Herring potential spawning habitat in the South Coast MAREA region; these activities are:

- Offshore renewable arrays;
- Trawl fisheries;
- Dredge fisheries;
- Cables and pipelines; and
- Dredge fines disposal sites.

The potential impacts associated with seabed infrastructure such as offshore renewable arrays, oil and gas pipelines and telecommunications cables are loss of habitat and egg mortality as a result of seabed disturbance during installation. Trawl and dredge fisheries actively target the seabed and as a result the potential impacts on potential Atlantic Herring potential spawning habitat from both types of fishing are egg mortality from seabed disturbance. Dredge fisheries may also result in the direct removal of eggs and alteration of habitat structure.

Table 4.4 quantifies the interaction between seabed user activities and 'heat' classes across the MAREA study region, noting the total footprint figures represent all seabed user interaction with 'heat' class, albeit with each sector interacting to a varying degree via different impact pathways. The results show that approximately 712 km2 of high 'heat' class, approximately 659 km2 of medium 'heat' class and approximately 1,499 km2 of low 'heat' class lies within the footprint of seabed user activity. This constitutes 92.3%, 93.3%, and 56.9% of the total available Atlantic Herring high, medium and low 'heat' classes in the South Coast MAREA region, respectively. The total value indicates that there is a degree of overlap between seabed user activity, with some areas of 'heat' class receiving impacts from more than a single sector i.e. the mobile activities such as dredge or trawl fishing overlap, to some degree, with the footprints of static activities.

Table 4.4 also shows that there are some areas where dredging activity, alone, interacts with 'heat' classes (i.e. there is no overlap with any other activity). Dredging, alone, overlaps with none of the high and medium 'heat' class, and approximately 90.5 km2 of low 'heat' class (Table 4.4). This comprises 3.4% of the low 'heat' class within the South Coast MAREA boundary. When considering these areas it should be noted that, in some cases, mobile fishing activity actively avoids dredging areas – and when dredging ceases it is likely that these areas will be targeted by fishing activity. It should also be noted that Table 4.4 presents a spatial analysis of the data only. No inferences on the respective significance of user activities are made.

Table 4.4: Footprint of Seabed User Activity on Atlantic Herring 'Heat' Class in the South Coast MAREA Region.

Seabed User Activity	Overlap with high 'heat' class (km^2)	% of total available high 'heat' class	Overlap with medium 'heat' class (km^2)	% of total available medium 'heat' class	Overlap with low 'heat' class (km^2)	% of total available low 'heat' class
Operating Windfarm Turbine Footprint	0	0	0	0	0	0
Operating Windfarm Licence Areas	0	0	0	0	0	0
Under Construction Windfarm Areas	0	0	0	0	0	0
Proposed Windfarms Indic. Turbine Footprint	0.02	0.002	0.15	0.02	0.64	0.02
Windfarm Licence Areas Proposed	11.27	1.46	56.71	8.03	276.19	10.48
Trawl Fishery	546.32	70.79	340.91	48.28	864.08	32.79
Dredge Fishery	557.87	72.29	318.49	45.10	558.36	21.19
Pipelines*	0	0	0	0	0.0013	4.9×10^{-5}
Power Cables*	0	0	0	0	0	0
Telecommunications*	0.0012	0.0002	0.0002	2.8×10^{-5}	0	0
Worst Case Proposed Power Cables*	0.0005	6.0×10^{-5}	0.0015	0.0002	0.0320	0.0012
Dredge Fines Disposal Sites	186.24	24.13	451.11	63.88	546.50	20.74
Dredging Activity (PIZ)	11.41	1.48	28.78	4.08	306.24	11.62
TOTAL	**711.9**	**92.25**	**658.9**	**93.30**	**1498.6**	**56.88**
Dredging Activity (PIZ) ONLY†	0	0	0	0	90.53	3.44

* Assumes that entirety of cable or pipeline is surface laid and not buried, and this therefore over represents footprint for these activities. † The area of seabed which has a footprint associated with dredging alone i.e. no overlap with any other activity

5. Discussion and conclusions

5.1. Stage 1 screening

Utilising the methods proposed in Reach *et al.* (2013) (as amended with Addendum) (Appendix A), and the associated confidence assessment protocol (Appendix B), the Stage 1 screening assessment successfully used multiple data layers to produce a 'heat' map indicative of potential Atlantic Herring spawning habitat. A wider regional sea area assessment, based on the use of seven data layers, has allowed the mapping of potential Atlantic Herring spawning 'hotspots' related to the southern North Sea and east English Channel. The data used vary from: seabed sediment data (BGS seabed sediments layer and MAREA-derived data); to spawning indicators such as Coull *et al.* (1998) and IHLS data from 2002-2011; along with fisheries VMS data and dedicated fisheries assessments (ESFJC Mapping Project data).

Each data layer has an associated confidence score and weighting according to its 'value' as an 'indicator of spawning' (Appendix B). Rules for combining the multiple data and interpreting the 'heat' map were developed and applied (see Appendix B for the methodology). The combined confidence ('heat' map) is the sum of all layer's 'value' scores at any one location. Four equal interval 'heat' classes have been derived from the data; low, medium, high and very high. The first three classes relate to the overlaps actually present within the data analysed and mapped, and represent classification of the range of 'value' of the data used: **low = 1-4**; **medium = 5-8**; and **high = 9-12**. The fourth category, **very high**, represents a theoretical maximum range of overlapping data that could be achieved if the spatial coverage of the data were different: theoretically, if the data used were updated in the future it may be possible that spatial ranges are extended resulting in increased numbers of overlaps. The very high 'heat' class has a range of 13-16. This process was agreed with the MMO and Cefas (Cefas, 2013a, 2013b; MMO, 2013b, 2013c).

As a result of the weighting assigned to the IHLS data layer, which indicates the presence of 0-ringer larvae (Section 3.4), the mapped areas of high 'heat' class (high confidence in Atlantic Herring potential spawning habitat presence) closely follows the boundaries of the IHLS data. Whilst it is possible that the limitations in the spatial coverage of the ICES IHLS data may introduce a bias into the analyses, the rationale from the ICES IHLS sampling strategy (ICES, 2012), and the known distribution of the Banks and Downs Atlantic Herring spawning populations, has been supplemented by extra data, where available (RPS, 2011). The distribution and extent of null data have been included in the analyses, along with total extent of survey coverage, providing the most comprehensive assessment of indicative larvae data possible. Whilst acknowledging certain constraints with the IHLS data (see Section 3.4 and Appendix L) these data still have the highest value and confidence attached to them.

It is evident from the assessment of the wider regional sea area that large areas of medium and high 'heat' (confidence and probability) Atlantic Herring potential spawning habitat occurs outside of the MAREA regions; and potentially even beyond the extent of the wider regional sea area considered – suggesting that such habitats are common in the southern North Sea and English Channel. Therefore a limiting factor for actual spawning may be related to biotic factors such as the actual current range of spawning populations (such as the Downs and Banks populations) rather than the availability of broadscale habitat.

A further limiting factor may be the presence of fine/micro-scale seabed features and bedforms that enhance an area as 'high value' spawning potential e.g. presence of gravel ripples and small ridge lines within high oxygenation. The detection and mapping of these micro-scale features are beyond the capability of the current macro-scale data to determine.

The Atlantic Herring potential spawning habitat assessment was focused by supplementing the BGS SBS v3 data layer with the MAREA seabed sediment interpretations, where appropriate, to produce marine aggregate-specific regional assessments. As discussed in Section 3.3 and Appendix M, the MAREA seabed sediment maps were selected as the base-map to assess the Humber and Anglian MAREA regions; whereas the BGS seabed sediment maps were chosen for the Outer Thames estuary and South Coast MAREA regions, and the 'outlier' licences. The interpretations of the data show that there are varying levels of confidence in the presence of potential spawning habitats within each of the MAREA regions.

Table 5.1: Summary of Stage 1 screening determinations

	PIZ Screened		SIZ Screened		Total Licences Screened	
Region	In	Out	In	Out	In	Out
Humber	33	0	33	0	**33**	**0**
Anglian	32	1	33	0	**33**	**0**
Thames	20	0	20	0	**20**	**0**
South Coast	57	0	57	0	**57**	**0**

The screening assessment was successfully carried out for all four of the MAREA regions, as well as the 'outlier' licences. In the Humber, Outer Thames and South Coast regions the PIZs and SIZs of all licence and application areas were screened in for EIA at site-specific level (Table 5.1), indicating that both the direct and indirect effects of dredging would have an impact on potential spawning habitats in these regions. In the Anglian region, the PIZ of Application Area 361/2 was screened out of requiring a site-specific EIA, indicating that there was no potential habitat present at the site as well as no other overlap with the fishery or spawning data layers. All the remaining Anglian region licence and application area PIZs were screened in for site-specific EIA. All SIZ's within the Anglian region, including Area 361/2, were screened into the site-specific EIA (Table 5.1).

As a result of all licence and application areas being screened in for site-specific EIA, it is apparent that there is a correlation between aggregate extraction areas and Atlantic Herring potential spawning grounds. This is not surprising, due to the focus of many aggregate extraction licences on coarser sediment fractions. Licence and application areas will interact to a greater or lesser degree with the potential spawning habitat, and the significance of the direct and indirect effects of dredging in individual licence areas will be assessed through a site-specific EIA. This will take into account the extent of high, medium and low 'heat' (confidence) areas within each MAREA region, as well as the degree of site-specific overlap with each of these areas of 'heat' (confidence levels).

5.2. Context for Atlantic Herring assessment

The Stage 2 assessments have determined the impact significance of aggregate extraction on Atlantic Herring potential spawning habitat through assessing the cumulative impacts of aggregate dredging, as well as in-combination interactions with other seabed users, at the MAREA scale.

The assessment of cumulative effects to Atlantic Herring has been undertaken in terms of assessing removal of eggs and loss/conversion of habitat, as opposed to assessing population level effects. The main basis of the assessment has comprised mapping Atlantic Herring potential spawning habitat, using data from various sources and to varying confidence levels as agreed with the MMO and Cefas. The likely cumulative significance of the effects of aggregate dredging has been assessed following a slightly modified version of the approach used in the MAREA. A simplistic and worst case approach has been followed which takes the footprint for marine aggregate extraction as comprising the licence areas and the secondary impact zones around them. This approach heavily overestimates the effects of dredging for two main reasons:

- In regard to egg removal (and smothering), this would only occur during a dredging event and when eggs were also present. The presence of eggs on the seabed and the presence of a dredger in the licence area are both limited duration events and may not necessarily be concurrent. Furthermore even if a whole licence area was covered with eggs a single or small number of dredging events would only affect a small portion of the area; and
- In regard to habitat loss/conversion it assumes that the totality of the licence area and a secondary zone around it would be converted from potentially suitable to wholly unsuitable habitat in regards to sediment composition. In reality there are several reasons why this is unlikely to actually happen, not least the monitoring and mitigation measures required of the industry in modern licence conditions.

So while the outcomes of the assessment may suggest possible minor or moderate cumulative impacts from dredging once the worst case approach taken is considered the effects are more likely to be not significant or minor at most.

There is also another factor to consider and that is the nature of Atlantic Herring spawning beds, which have quite specific characteristics. While it is not a fault of the assessment, this regional study has looked at data at a macro-scale that does not allow the necessary resolution to actually identify specific discrete and individual areas of seabed with the potential to act as Atlantic Herring spawning beds. This is mainly because Atlantic Herring spawning beds are typically small localised features. For example a study undertaken by NOAA records size ranges of Atlantic spawning beds between 0.067 km^2 and 1.39 km^2 (Reid *et al.*, 1999). A second study reported for Irish waters by The Marine Institute, Fisheries Ecosystems Advisory Services, cites that the smallest beds were found predominantly in the Celtic Sea, where nine beds were not larger than 0.1 km^2. The largest bed in the Celtic Sea was recorded as 36 km^2. In contrast spawning grounds recorded in the north and northwest of Irish waters, were considerably larger, with the largest being nearly 170 km^2, off north Donegal (O'Sullivan *et al.*, 2013). However, for the larger spawning sites it is unclear whether they are contiguous beds, which seems unlikely given the specific spawning habitat requirements of Atlantic Herring.

Based on a number of sources providing information on egg density at Atlantic Herring spawning beds, number of eggs per female herring and the spawning stock biomass it is possible to estimate a possible range for the total area of suitable spawning habitat for the North Sea Atlantic Herring population and then compare this with the values predicted in the Phase 1 mapping work. It should be noted that this is not a scientific attempt to quantify total Atlantic Herring spawning habitat, but rather to allow order of magnitude comparisons of values predicted in two different ways.

The North Sea spawning stock[6] biomass is currently in the order of 1.7 million tonnes (http://www.scotland.gov.uk/Publications/2012/05/9899/8). Taking the average weight of an adult Atlantic Herring as 0.225 kg this would equate to a spawning population of approximately 7,555,555,556 fish (see http:// www.clupea.net/stocks/NEAtlStocks/NorthSeaHer/NSAS_weca.htm). According to Stratoudakis *et al*. (1998), on prime Atlantic Herring spawning beds, egg densities were measured at 750,000 to 2,500,000 eggs per m^{-2}. An adult female herring carries between 20-50,000 eggs (http://www.gma.org/herring/biology/life_cycle/default.asp). These values equate to anything between 15 and 125 female herring per m^2, or 30 to 250 adult fish per m^2 in total (assuming one male per spawning female). Taking a mean number of eggs per m^2, and a mean number of eggs per female, yields a mean number of females of 46 per m^2, and a total of 92 fish per m^2. At these spawning densities, 7,555,555,556 fish would require a total area of prime habitat in the range of 30 to 252 km^2, with a mean of 82 km^2.

By comparing these estimated values with the measured values of 'heat' from the CIAs (representing confidence in the presence of potential spawning habitat) it is possible to assess the scale of available habitat in the context of prime habitat as detailed above (see Table 5.2). Therefore assuming initially that high 'heat' equates to prime habitat it is evident that all regions, with the exception of the Anglian, exceed the mean value of 82 km^2. The Anglian region with 47 km^2 of high 'heat' seabed does fall within the calculated range of prime habitat requirement of 30 to 252 km^2. If medium 'heat' seabed habitat is also factored then all of the regions have adequate habitat space within which prime habitat (as described above) could be located.

In reality actual spawning habitat or habitat that could be used in the future will likely comprise relatively small seabed features as noted above. While it will be the role of site-specific EIAs, and associated monitoring as part of the licence conditions, to determine the potential presence of such habitat features, it is still possible to make some conclusions at this stage. In terms of a micro-scale identification, it is clear from a review of the literature that the best indicator of a seabed feature being suitable for Atlantic Herring spawning habitat is when it comprises a fisherman's 'mark' for targeting herring while they are spawning (see O'Sullivan *et al.*, 2013). O'Sullivan *et al.* (2013) provide examples of a series of interviews held with experienced Atlantic Herring fishermen, with each having extensive knowledge of targeting spawning herring in a particular coastal area. This information, including distribution and extent of spawning beds was considered to be reliable, because it was based on experience obtained during the period when fishermen actively targeted spawning fish to obtain roe (eggs) (O'Sullivan *et al.*, 2013).

[6] Including Banks, Downs and also the Buchan and Orkney/Shetland populations, the latter two populations are screened out this study envelope (see Section 3.1 and Appendix A)

Table 5.2: Area of Atlantic Herring potential spawning habitat related by 'heat' for the MAREA areas assessed

'Heat' Class	Area of 'Heat' Class (km^2)			
	Humber	Anglian	Thames	South Coast
Low	2,468	1,991	797	2,635
Medium	3,417	1,811	2,969	706
High	2,202	47	326	772
Very High	0	0	0	0

To date there has not been a single objection raised by Atlantic Herring fishermen to any marine aggregate extraction licence application in any of the regions assessed as part of this study (based on pers. comm. between the EIA WG and the operators (clients) that have commissioned this study). Together, and in the absence of any other evidence to the contrary, these factors can be taken as a reasonable indication that no such 'marks' delineating Atlantic Herring spawning beds exist within any marine aggregate licence areas in the Humber, Anglian, Outer Thames Estuary or South Coast regions.

As O'Sullivan *et al.* (2013) have shown, the information regarding the location of fishermen's 'marks' is an extremely useful data source regarding evidence for spawning grounds. As part of their study O'Sullivan *et al.* (2013) presented the 'mark' data in a coarse resolution within the report to protect the commercial competitiveness of that knowledge. Higher resolution data is available to the regulator and statutory bodies for the purposes of fisheries management. If the MMO or RAG deems that it is an appropriate avenue to seek further evidence, then O'Sullivan *et al.* demonstrate that this is best delivered through a concerted, organised manner by a statutory body, or agent acting on behalf of that body. The current marine planning co-ordinated by the MMO may be such an appropriate mechanism to approach acquiring these data in English waters.

5.3. Stage 2 regional cumulative impact assessments

The CIAs produced for Stage 2 highlight the cumulative impact significance of marine dredging activities on Atlantic Herring potential spawning habitats. Table 5.3 summarises the significance of the effects determined for each of the MAREA regions.

Table 5.3 shows that for most effects, across most regions, minor and not significant levels of significance are assessed. The Humber and, in particular, the Outer Thames Estuary CIAs do assess some of the cumulative effects to be of moderate significance. This will, in part, be due to the presence of higher potential spawning activity present in these regions when compared with the Anglian and South Coast regions. This relates to licence and application area overlap with Atlantic Herring larvae (as collected by the IHLS) (Figure 5.1). Whilst other regions support Atlantic Herring spawning, it is the Thames and Humber which have the greatest areas of overlap with the IHLS data (Figure 5.1).

Table 5.3: Summary of impact significance determinations for cumulative dredging effects on Atlantic Herring Potential Spawning Habitat for each of the four MAREA regions

Effect	Humber	Anglian	Thames	South Coast
Direct removal of suitable habitat	Minor	Minor	Moderate	Minor
Direct removal of eggs	Moderate	Not significant	Moderate	Not significant
Alteration of habitat structure	Minor	Minor	Moderate	Minor
Sand deposition resulting in smothering of eggs	Minor	Not significant	Moderate	Minor
Fining of suitable habitat	Minor	Not significant	Moderate	Minor

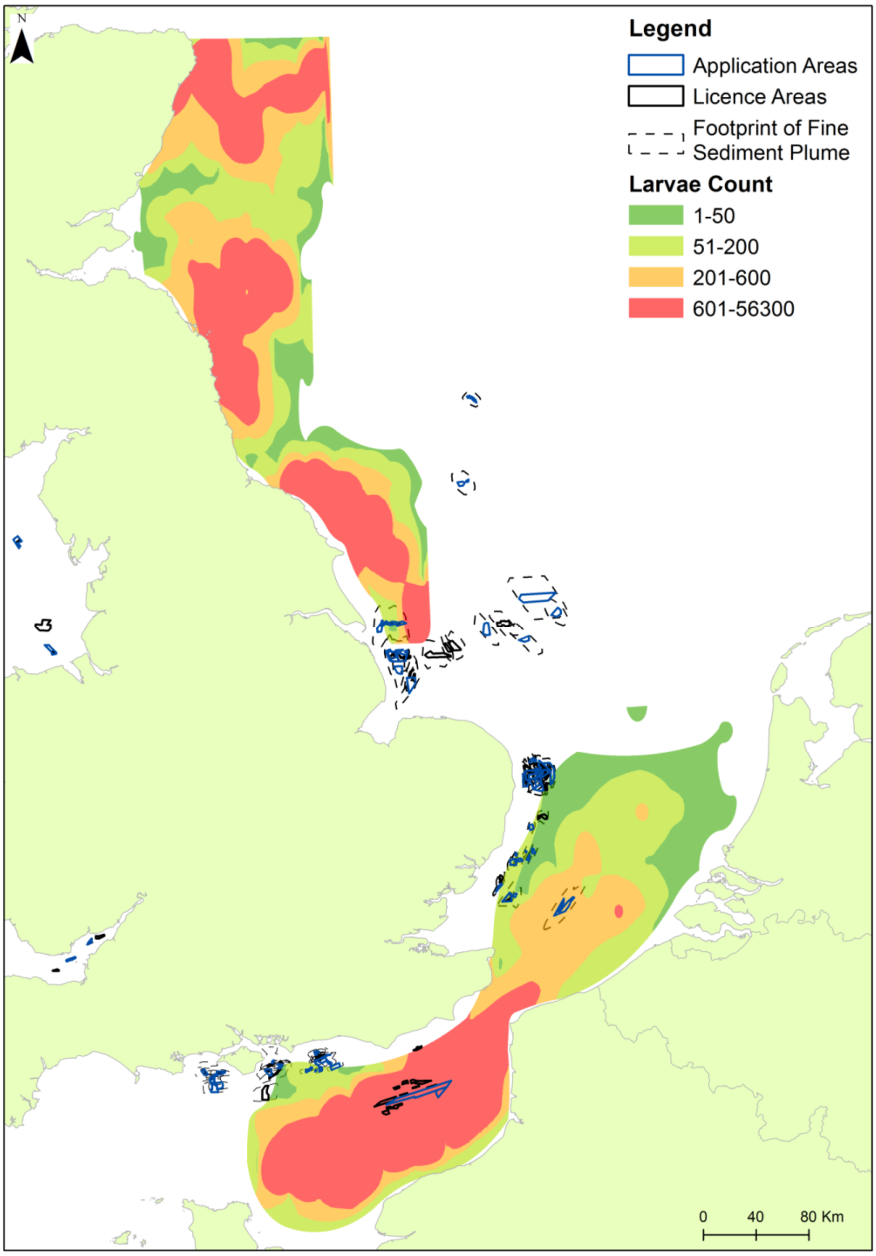
The magnitude of directly removing potential spawning habitat by dredging has been assessed as varying between very low and medium, based on the spatial overlap with IHLS data, the relatively short duration of dredger visits and intermittent frequency of visits. The sensitivity of Atlantic Herring to habitat removal has been assessed as medium and medium-high. It has been noted that this could have been higher if there were no other potential spawning habitats in the regions, however it should also be noted that the determinations represent a conservative outcome given the working assumption that the entirety of the PIZ and SIZ would be impacted, when the reality is that only a very small portion of each would be affected at any moment in time.

The mitigation measure to leave in place, post-dredging, a layer of seabed sediment similar to that which existed before dredging began, allows recovery and recolonisation and reduces the sensitivity of the receptor.

The direct removal of eggs through aggregate extraction also varies in significance, based on the likelihood of interaction with dredging. It has been recognised that interaction between eggs and the draghead would only be possible for a short period of time while eggs were on the seabed, and would also be very limited spatially. As such the magnitude of interaction is higher in the Humber and Outer Thames regions than in the Anglian and South Coast where larval numbers (according to IHLS) are lower. Regardless of magnitude, the sensitivity of direct removal of eggs has been classed as between medium and high for all the regions, recognising the potential impact on larval numbers.

The alteration of habitat within the PIZ is assessed as of minor significance within the Humber, Anglian and South Coast MAREA regions, and of moderate significance in the Outer Thames estuary region. The duration and frequency of visits, combined with the mitigation measure to leave a layer of resource sediment on the seabed, after dredging, on average 0.5 m thick is likely to restrict any change to spawning habitats. It is assessed that Atlantic Herring could be temporarily displaced, however as Atlantic Herring spawning has been shown to be geographically variable from year-to-year, with a wide larval dispersal pattern and a limited amount of site fidelity in relation to the total possible herring spawning habitats demonstrated at a wider regional sea area (Bowers, 1980; Rankine, 1986; Aneer, 1989; Stephenson and Power, 1989; Coull *et al.*, 1998; Stratoudikis *et al.*, 1998; Maravellias *et al.*, 2000; Morrison *et al.*, Maravellias, 2001; Mills *et al.*, 2003; Skaret *et al.*, 2003; Geffen, 2009; Payne, 2010; ECA and RPS Energy, 2010a, 2010b, 2011; Ellis *et al.*, 2012) it is expected that spawning will occur on other available similar habitat within the MAREA regions.

Figure 5.1: Interpolation of International Herring Larvae Survey data for the period 2002-2011. (Derived from ICES IHLS data for 2002-2011)



The smothering of eggs by sand deposition has been seen to lead to retardation of larval development and mortality (Griffen *et al.*, 2009). Despite this, Atlantic Herring eggs are only present on the seabed for a short period of time (Stratoudakis *et al.*, 1998) in specific areas and, as a result, the likelihood of eggs being exposed to finer sediments is reduced. The range of significance determinations again reflects the relatively higher exposure of larvae within the Outer Thames region. The Not Significant determination for the Anglian region reflects the higher amounts of relatively mobile sandy sediments which, in conjunction with the limited IHLS larvae data, suggest that the Anglian region may not be a favourable area for Atlantic Herring spawning habitat (See Figure 3.1a and b for the known extent and location of Atlantic Herring spawning populations derived from IHLS data, including areas of null data).

The fining of sediments within the SIZs has been assessed as being of limited extent and duration, returning to previous conditions relatively quickly. Additionally any potential impacts on Atlantic Herring spawning activities are expected to be minimised due to the availability of other potential spawning habitats within the MAREA regions. As a result low levels of significance have been assigned to this effect for the Humber, Anglian and South Coast regions, whereas the high value of Atlantic Herring in the Thames and the overlap with IHLS data has raised the determination into the moderate significance category for the Outer Thames estuary region.

All CIAs indicate that, providing a layer of suitable seabed sediment is retained at the site post-dredging, the recovery and re-colonisation of aggregate areas as spawning locations will be possible. As previously mentioned Atlantic Herring has been shown to be geographically variable from year-to-year, with a wide larval dispersal pattern and a limited amount of site fidelity and as such it has been observed that if appropriate habitat exists it can be used as a spawning site (i.e. in relation to the total possible herring spawning habitats demonstrated at a wider regional sea area).

The MAREAs assigned a **high value** to Atlantic Herring based on the commercial importance of the area as a nursery ground maintaining sustainable levels of recruitment, as well as the species being a UK Biodiversity Action Plan priority species.

However as agreed with MMO (2013a) this assessment is not required to assess effects to the Atlantic Herring population as a whole but to focus primarily on egg removal and habitat loss/conversion. The varying degrees of importance of seabed habitat to Atlantic Herring (and also therefore the likelihood of encountering eggs) have been mapped and as a result the 'value/importance' term is integrally addressed in determining the degree of overlap between marine aggregate extraction and potentially suitable herring spawning habitat. For this reason the 'value/importance' term as a standalone criterion in determining significance as it was adopted in the MAREA approach is questionable since it would effectively lead to double-counting. Therefore the overall sensitivity value could be assessed as **medium**. If this value is used then the impact significance determinations for cumulative dredging effects on Atlantic Herring Potential Spawning Habitat for each of the four MAREA regions could effectively be down-graded to **Minor** or **Not Significant** across all of the regions assessed, including the Outer Thames Estuary. The only possible exception may be direct removal of habitat sediment in areas of high 'heat' which could be assessed as **Minor-Moderate** significance.

The individual CIA assessment determinations are presented in Table 5.3 but it is important to consider the possible adjustment, and down-grading of impact significance, adopting the rationale explained above.

The scale of dredging can also be put into a wider context by comparing the relative contributions of other seabed users within the wider regional sea area, as shown in Figure 5.2 (defined by the BGS SBS v3 coverage) and Table 5.4.

Figure 5.2: The wider regional sea area considered relevant to this assessment for Atlantic Herring potential spawning habitat.

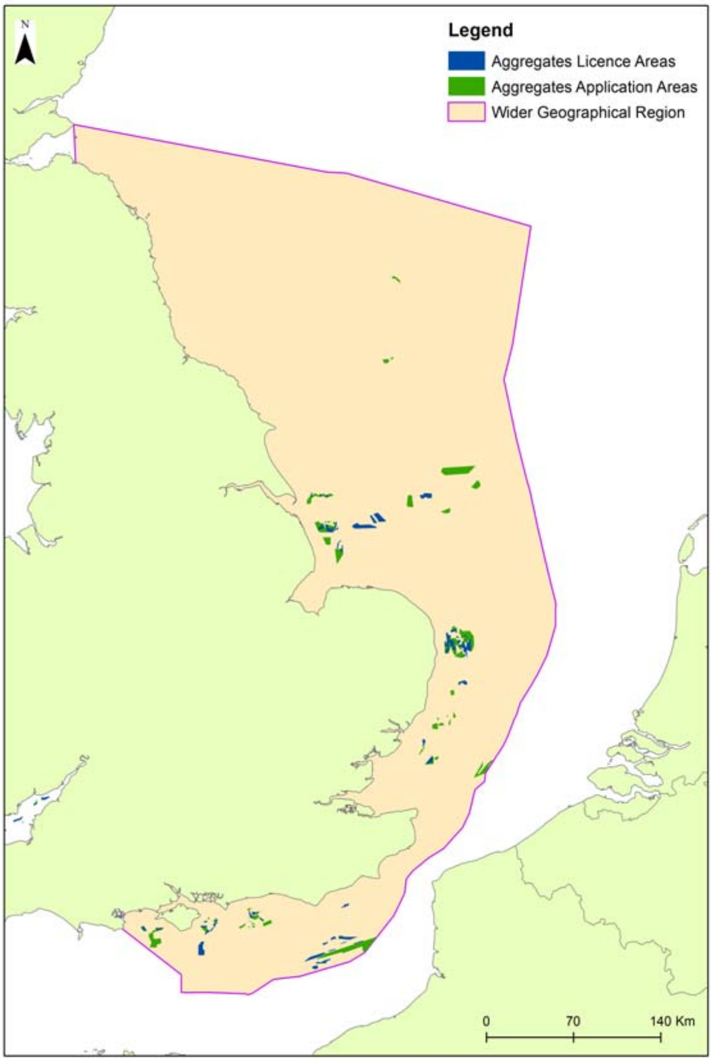


Table 5.4 shows the relative contributions of each seabed user to the pressure on Atlantic Herring potential spawning habitat across the wider regional sea area. The total area of Atlantic Herring low, medium and high 'heat' within the wider regional sea area is approximately 12,504.23 km^2, 34,471.21 km^2, and 23,139.38 km^2, respectively. Table 5.4 shows that 16,098.13 km^2 (69.6%) of the total low 'heat' in the wider regional sea area is overlapped by the activities of seabed users, including marine aggregates. A total extent of 26,128.01 km^2 (75.8%) related to seabed user footprint overlaps with medium 'heat' and 9,556.65 km^2 (76.4%) with high 'heat'.

As might be expected, demersal trawl fishing overlaps the largest areas of Atlantic Herring potential spawning habitat, with over 8,430 km^2 of high 'heat' seabed (67.4% of the wider regional sea area 'high' heat total) and over 23,467 km^2 of medium 'heat' seabed (68.1% of the wider regional sea 'medium' heat area). There is also an overlap with low 'heat' seabed of 13,298 km^2 (57.5% of the wider regional sea 'low' heat area).

Table 5.4: Total Footprint of Seabed User Activity on Atlantic Herring Potential Spawning Habitat in the Wider Regional Sea Area (based on the BGS SBS v3 extent).

Seabed User Activity	Overlap with high 'heat' class (km^2)	% of total available high 'heat' class	Overlap with medium 'heat' class (km^2)	% of total available medium 'heat' class	Overlap with low 'heat' class (km^2)	% of total available low 'heat' class
Operating Windfarm Turbine Footprint	0.066	0.000	0.837	0.002	0.224	0.001
Operating Windfarm Licence Areas	0.000	0.000	67.788	0.197	28.491	0.123
Under Construction Windfarm Areas	27.179	0.217	201.393	0.584	14.966	0.065
Proposed Windfarms Indicative Turbine Footprint	1.200	0.001	12.515	0.036	11.527	0.050
Windfarm Licence Areas Proposed	512.679	4.100	5305.436	15.390	4875.055	21.068
Trawl Fishery	8430.525	67.421	23467.671	68.079	13298.250	57.470
Dredge Fishery	5685.947	45.472	3210.507	9.314	1305.502	5.642
Pipelines*	0.174	0.001	0.664	0.002	1.101	0.004
Power Cables*	0.036	0.000	0.070	0.000	0.036	0.000
Telecommunications*	0.031	0.000	0.074	0.000	0.038	0.000
Worst Case Proposed Power Cables*	0.068	0.001	0.078	0.000	0.055	0.000
Dredge Fines Disposal Sites	420.558	3.363	3136.334	9.098	600.828	2.597
Dredging Activity (PIZ)	1054.886	8.436	766.562	2.224	1131.184	4.889
TOTAL	**9556.650**	**76.429**	**26128.007**	**75.797**	**16098.131**	**69.570**
Dredging Activity (PIZ) ONLY[†]	59.884	0.479	160.065	0.464	523.304	2.262

* Assumes the entire cable or pipeline is surface laid and not buried, and this therefore over represents footprint for these activities. † The area of seabed which has a footprint associated with dredging alone i.e. no overlap with any other activity.

When considering overlap with Atlantic Herring potential spawning habitat, the analyses showed (Table 5.4) that trawl fishing, dredge fishing and dredge fines disposal sites all have larger overlaps with both medium and high 'heat' areas than dredging activity does.

For low, medium and high 'heat' overlap the 'worst case' footprint for offshore renewable projects (proposed) is less than that from marine aggregate dredging activity. Further, this interaction is only indicative, as there is a high level of precaution in the comparison of these two footprints. First, the marine aggregate footprint (as described in Section 2) assumes the total area of the licence or application area will be dredged and contribute to seabed/egg impacts. Second, the project footprint for offshore renewables is also based on the assumption that the whole area of the array will result in seabed/egg impacts. Reference to the preceding value for operating turbine footprint shows that the actual loss of seabed is orders of magnitude smaller, when the areas associated with actual installed foundations is considered (it should be noted that this is based on UK Round 1 and 2 builds generally using 5-6 m diameter monopiles). The indicative turbine footprint areas (for proposed offshore windfarms) are calculated assuming 'worst case' for UK Round 3, which will likely use a mixture of foundation types including steel jacket and concrete gravity base. These deeper water foundation types all have significantly larger seabed footprints than 5-6 m steel monopiles (Reach *et al.*, 2012).

Of the seabed users summarised in Table 5.4, offshore windfarms, power and telecommunication cables, and pipelines have a smaller spatial overlap with Atlantic Herring potential spawning habitat recorded as low, medium or high 'heat' in the wider regional sea area than dredging activity does.

A further consideration to the overall interaction is the degree of overlap between seabed users, with some areas of seabed receiving impacts from more than a single sector. Mobile activities such as dredge or trawl fishing are shown to overlap, to some degree, with the footprints of all static activities (except for the exact location of installed wind turbine foundations).

Table 5.4 also shows that there are some areas of the wider regional sea area where dredging activity, alone, interacts with potential spawning habitats (i.e. there is no overlap with any other activity). Dredging, alone, overlaps with approximately 523.3 km^2 of low 'heat' potential spawning habitat, approximately 160.1 km^2 of medium 'heat' potential spawning habitat in the wider regional sea area, and approximately 59.9 km^2 of high 'heat' seabed (Table 5.4). This accounts for 2.3% of low 'heat' potential habitat, 0.5% of the medium 'heat' potential spawning habitat, and 0.5% of high 'heat' seabed within the wider regional sea area, respectively. When considering these areas, it should be noted that these analyses represent a conservative outcome, given the working assumption that the entirety of the PIZs and SIZs would be impacted, when the reality is that only a very small portion of each would be affected at any moment in time. Areas of similar Atlantic Herring potential spawning habitat also occur outside of the wider regional sea area analysed, and it should also be noted that, in some cases, mobile fishing activity actively avoids dredging areas – and when dredging ceases it is likely that these areas will be targeted by fishing activity.

5.4. Conclusions

While the determinations for individual licence areas will be site-specific, Table 5.3 suggests that, in general, effects on potential Atlantic Herring potential spawning habitat are likely to be of minor or no significance. In some cases, the assessed effects may have a higher significance, although it is unlikely that this will be assessed as higher than moderate significance. This is partially due to the wide spatial distribution of potential spawning habitat available to the Downs and Banks Atlantic Herring populations and identified by the IHLS and Stage 1 assessments. These populations have a wide availability of preferred and marginal sediment habitat both within the MAREA regions assessed as part of this project, and extending beyond the MAREA boundaries into the southern North Sea and English Channel. Within the wider regional sea area, approximately 35,168 km^2 of seabed habitat is available breaking down as 17,046 km^2 of preferred habitat sediment classes and 18,122 km^2 of marginal habitat sediment class. There is 23,139 km^2 of low 'heat' seabed, 34,471 km^2 of medium 'heat' seabed and 12,504 km^2 of high 'heat' seabed within the wider regional sea area assessed.

It is important to note that the significance of impacts over the long-term is reduced by the industry standard practice of leaving a layer of resource sediment on the seabed, after dredging (on average 0.5 m thickness). This means that the overall area of preferred and marginal habitat sediments available for Atlantic Herring spawning does not change significantly post-dredging. In addition recovery and recolonisation of areas can occur quickly once dredging has ceased (Tillin *et al.,* 2011; Hill *et al.*, 2011).

While a degree of variation is expected between regions and licence areas, based on spatial coverage of the data layers, the results of the in combination spatial assessments and CIAs for the MAREA regions indicate that while Atlantic Herring potential spawning habitat is under pressure from anthropogenic activity, dredging activity only contributes to a small proportion of the spatial interaction with areas of seabed likely to represent spawning grounds, or have the potential to be spawning grounds, in comparison with other anthropogenic activities.

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7. Appendices

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Appendix A: Screening Spatial Interactions between Marine Aggregate Application Areas and Atlantic Herring Potential Spawning Habitat: A Method Statement

Addendum to Screening Spatial Interactions between Marine Aggregate Application Areas and Atlantic Herring Potential Spawning Habitat: A Method Statement

The Marine Aggregate Environmental Impact Assessment Working Group has revised the methodology in (Reach *et al.*, 2013[7]), specifically with regard to the parameterisation and classification of potential spawning habitat and the associated sediments that underpin the habitat. No Folk sediment classes have been added or subtracted from the methodology. The re-classification has merely built upon the similar sandeel habitat classification rationale that has been developed in parallel with this methodology (Latto *et al.*, 2013[8]).

It is also important to note that both Reach *et al.* (2013) and Latto *et al*. (2013) should include an appendix containing the confidence assessment protocol and methodology (as attached as Appendix B to this report).

The Folk sediment classification (Folk, 1954) has been used to describe seabed habitat as this is also the classification scheme used to underpin the British Geological Survey's (BGS's) 1:250,000 scale seabed sediment maps. This sediment classification has subsequently been used within the Marine Aggregate Regional Environmental Characterisation (REC) and MAREA reports. Using the Folk (1954) classification enables compatibility of the Atlantic Herring potential spawning habitat environmental assessments with a range of products (e.g. MAREAs, marine planning areas) and data sources (e.g. BGS 1:250,000 maps).

The review and analysis of the source data for potential spawning habitat (see Reach *et al.*, 2013) resulted in the development of the seabed sediment classification presented in Figure A1. The sediment divisions, referred to as **habitat sediment classes** (using the Folk (1954) sediment classification), have the potential to support Atlantic Herring spawning and are presented in Tables A1 and A2. The alteration to the previous Atlantic Herring potential spawning habitat classification regards the sub-division of the potential spawning habitat, re-classification of preferred habitat sediment classes, and the allocation of a marginal habitat sediment class.

It is important to note and clarify that the habitat sediment classification is not the only parameter (datum) that indicates potential spawning habitat. There are other environmental (physical, chemical and biotic) parameters such as: oxygenation, siltation, overlap with range of spawning populations, micro-scale seabed morphological features e.g. ripples and ridges; which all contribute to the suitability of seabed habitat to be used as spawning beds by Atlantic Herring.

Considering the wide range of environmental parameters that determine Atlantic Herring spawning, it is important to note that the use of the habitat sediment classes alone will always over-represent

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[7] Reach I.S., Latto P., Alexander D., Armstrong S., Backstrom J., Beagley E., Murphy K., Piper R. and Seiderer L.J., 2013. *Screening Spatial Interactions between Marine Aggregate Application Areas and Atlantic Herring Potential Spawning Areas.* A Method Statement produced for BMAPA.

[8] Latto P. L., Reach I.S., Alexander D., Armstrong S., Backstrom J., Beagley E., Murphy K., Piper R. and Seiderer L.J., 2013. *Screening Spatial Interactions between Marine Aggregate Application Areas and Sandeel Habitat.* A Method Statement produced for BMAPA.

the range of habitat with the potential to support Atlantic Herring spawning events. This results in the rationale for using as many indicative data layers as possible and determining representation of potential for spawning based on the 'heat' of the spatial overlaps (of the data used).

Table A1: Description of Atlantic Herring potential spawning habitat sediment classes. (Adapted from: Reach *et al.*, 2013)

Preferred habitat sediment class	In the context of this methodology these are the sediment divisions/units represented by Gravel and sandy Gravel which Atlantic Herring favourably select as part of their spawning habitat requirements. It should be noted that other physical, chemical and biotic factors contribute to the overall definition of potential spawning habitat – see also *Prime* and *Sub-prime* descriptions.
Marginal habitat sediment class	In the context of this methodology this is the sediment division/unit represented by gravelly Sand which Atlantic Herring may select as part of their spawning habitat requirements. This sediment class has adequate sediment structure but is less favourable than preferred habitat – see also *Suitable* descriptions
Unsuitable habitat sediment class	Seabed sediment classes which have inadequate sediment structure to be chosen by Atlantic Herring for spawning grounds
Prime Habitat Sediment Class	In the context of this methodology these are the sediment divisions/units represented by Gravel and sandy Gravel with ideal sediment structure that supports Atlantic Herring spawning activity – see also *preferred habitat sediment class*. It should be noted that other physical, chemical and biotic factors contribute to the overall definition of potential spawning habitat
Sub-prime Habitat Sediment Class	In the context of this methodology this is the sediment division/unit represented by gravelly Sand which has acceptable sediment structure and supports Atlantic Herring spawning activity This sediment class has adequate sediment structure but is less favourable than *prime habitat sediment*– see also *preferred habitat sediment class*
Suitable habitat sediment class	Atlantic Herring habitat sediment which has adequate sediment structure but is likely to only support low density of spawning activity. This represented by gravelly Sand Folk sediment class – see also *marginal habitat sediment class*

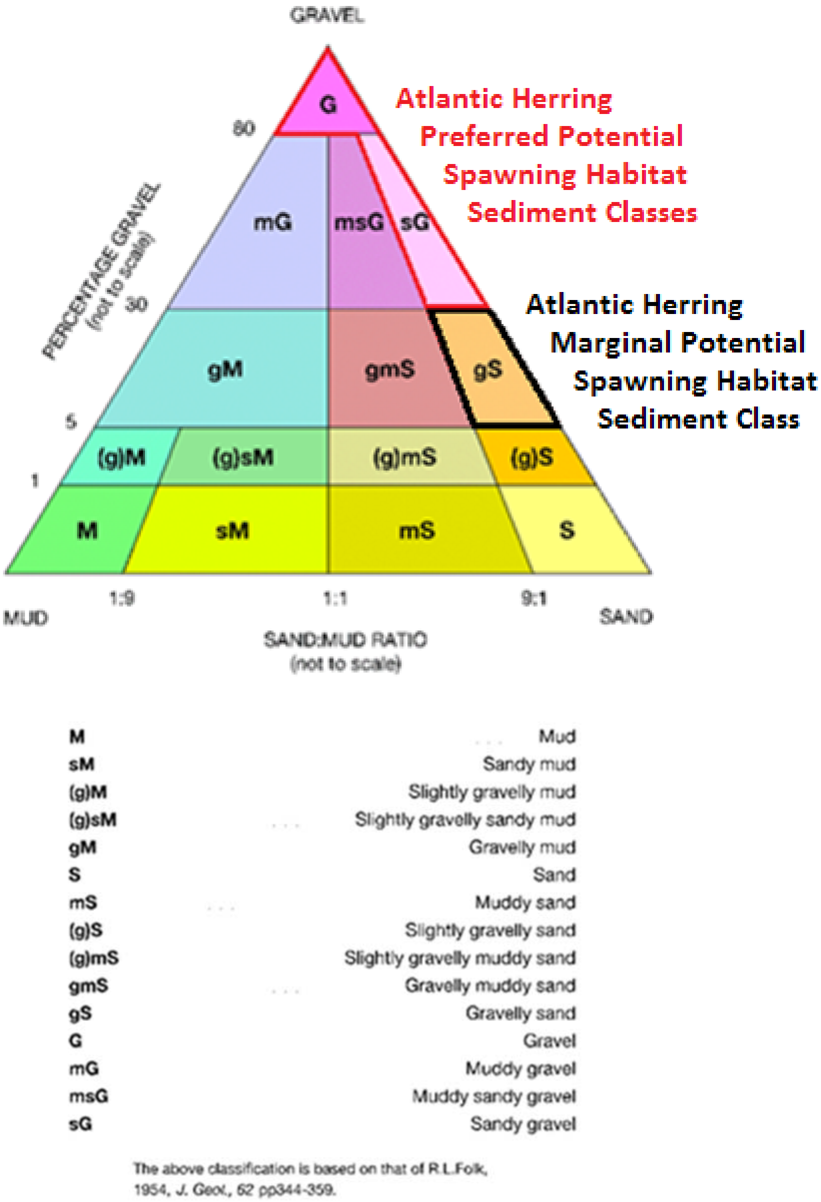
Table A2: The partition of Atlantic Herring potential spawning habitat sediment classes. (Source: Folk, 1954; adapted from Reach *et al.*, 2013)

% Particle contribution (Muds = clays and silts <63 µm)	Habitat sediment preference	Folk sediment unit	Habitat sediment classification
<5% muds, >50% gravel	Prime	Gravel and part sandy Gravel	**Preferred**
<5% muds, >25% gravel	Sub-prime	Part sandy Gravel and part gravelly Sand	**Preferred**
<5% muds, >10% gravel	Suitable	Part gravelly Sand	**Marginal**
>5% muds, <10% gravel	Unsuitable	Everything excluding Gravel, part sandy Gravel and part gravelly Sand	**Unsuitable**

This habitat sediment classification, and the sediment divisions used, was ratified by the MMO and RAG at a meeting held on 01 May 2013 (MMO, 2013[9]). It is important to note that the Folk (1954) sediment classes over-represent the suitability of an individual class to completely represent sediment habitat that will be used by Atlantic Herring for spawning. This is due to the percentage of muds component within the sediment divisions. However without a complete re-working of all the BGS data used in developing the 1:250,000 scale sediment maps a direct representation of the <5% muds (<63 µm) is not possible. The MMO and RAG agreed that such an exercise is beyond the requirements of any specific EIA (as required under the MWR). Therefore the best-fit Folk sediment classification, presented in amended form as Figure A1, has been used to conduct the assessments within this report. This updates the Folk triangle presented and used in Reach *et al.* (2013).

[9] Marine Management Organisation (MMO), 2013a. Note of the MMO and RAG Atlantic Herring potential spawning habitat mapping methodology meeting held on 01 May 2013.

Figure A1: The Folk sediment triangle with Atlantic Herring preferred and marginal habitat sediment classes indicating potential spawning habitat. (Source: Folk, 1954; adapted from Reach *et al.*, 2013)



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Appendix B: Confidence Assessment Protocol

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Appendix C: Data layers used for screening Humber MAREA region licence and application areas

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Appendix D: Data layers used for screening Humber outlier region licence and application areas

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Appendix E: Data layers used for screening Anglian MAREA region licence and application areas

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Appendix F: Data layers used for screening Outer Thames Estuary MAREA region licence and application areas

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Appendix G: Data layers used for screening South Coast MAREA region licence and application areas

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Appendix H: Humber regional cumulative impact assessment

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Appendix I: Anglian regional cumulative impact assessment

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Appendix J: Outer Thames Estuary regional cumulative impact assessment

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Appendix K: South Coast regional cumulative impact assessment

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Appendix L: *Proviso* of specific stipulations, conditions, or limitations regarding data used in the report and cumulative impact assessments as indicated by the Marine Management Organisation and/or its statutory and technical advisors (the RAG)

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Appendix M: Seabed habitat sediment maps

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