Appendices to:

Environmental Effect Pathways between Marine Aggregate Application Areas and Atlantic Herring Potential Spawning Habitat: Regional Cumulative Impact Assessments. Version 1.0.

A report for the British Marine Aggregates Producers Association by MarineSpace Ltd, ABPmer Ltd, ERM Ltd, Fugro EMU Ltd and Marine Ecological Surveys Ltd, 2013.

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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[1]), 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[2]).

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 the range of habitat with the potential to support Atlantic Herring spawning events. This results in

[1] 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.

[2] 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 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*

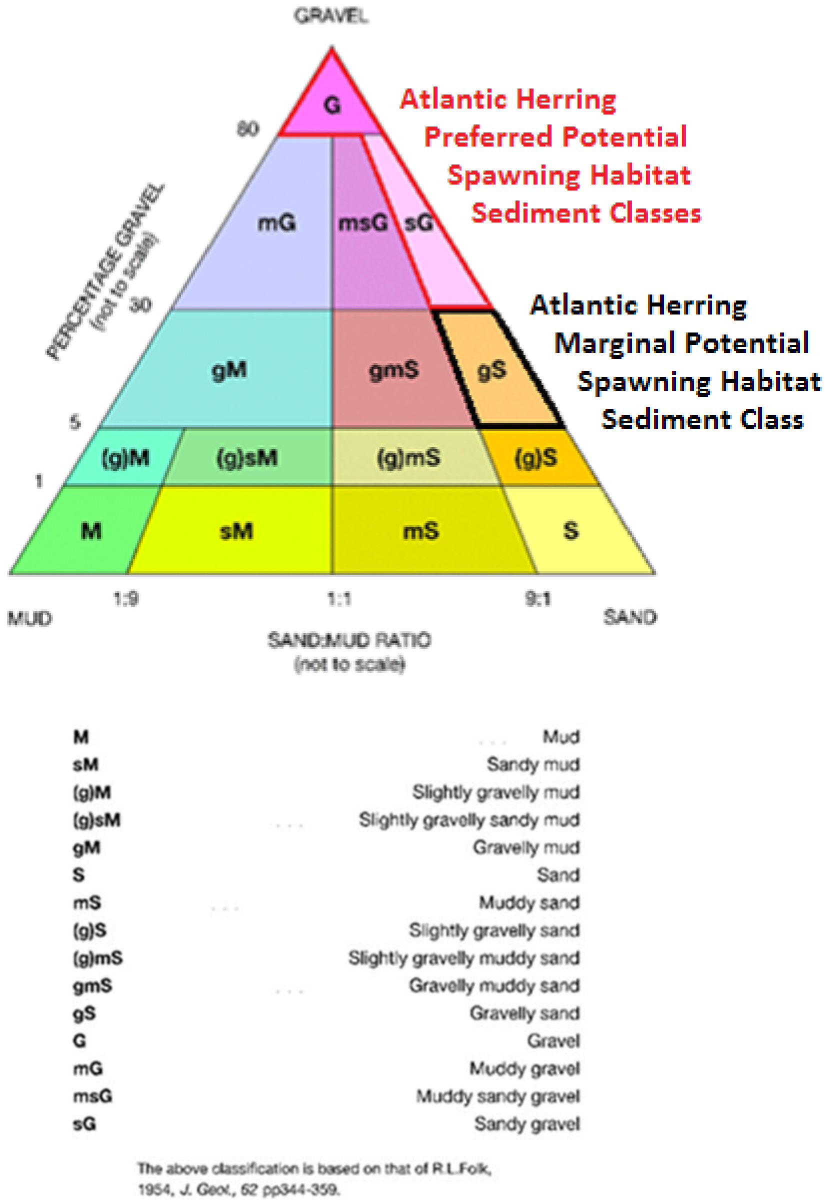
Table A2: The partition of Atlantic Herring potential spawning habitat sediment classes. (Source: Folk, 1954; adapted from Reach *et al.*, 2013)

% 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[3]). 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).

[3] 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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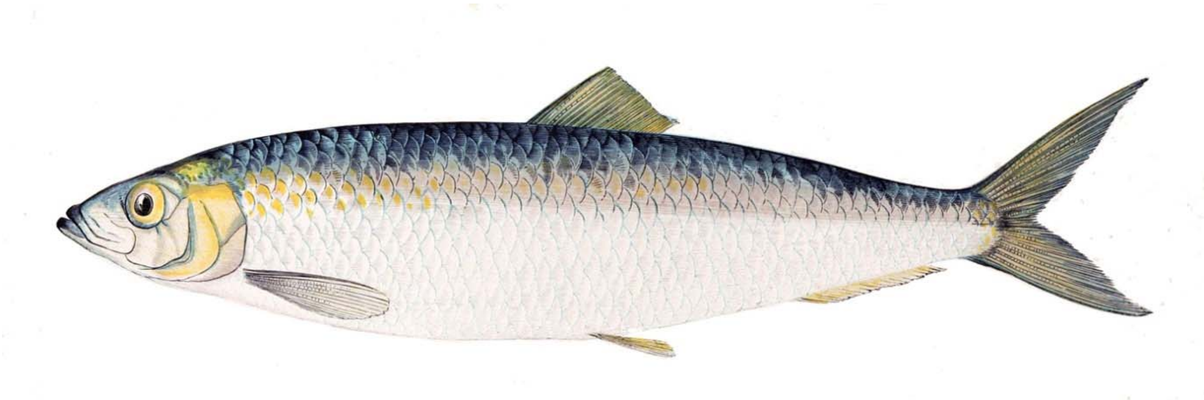
Screening Spatial Interactions between Marine Aggregate Application Areas and Atlantic Herring Potential Spawning Habitat:

A Method Statement



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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.

Readers should note that this publication is subject to periodic revision and should ensure that they are in possession of the latest version.

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 permitted to occur
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
	Benthic	Relating to the seabed or organisms that live there
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
DEAL	Digital Energy Atlas and Library	A web-based service which provides information about UK exploration and production of hydrocarbons on the UKCS
DECC	Department of Energy and Climate Change	The Government department acting as the Regulator regarding energy infrastructure plans and

		projects
	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^{o}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
JNCC	The Joint Nature Conservation Committee	The Government's statutory advisor on the marine natural environment from 12 to 200 nm 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
Marine Aggregate EIA WG	Marine Aggregate Environmental Impact Assessment Working Group	A quorum 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 licenses

NE	Natural England	The Government's statutory advisor on the English natural environment out to 12 nm
PINS	The Planning Inspectorate	A Governmental executive agency responsible for determining final outcomes of planning and enforcement appeals and public examination of local development plans
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
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 licenses
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
	Subsea Cables UK	An organisation of submarine cable owners, operators and suppliers, primarily aimed at promoting marine safety and protecting cable installations on the UKCS
UKCS	United Kingdom Continental Shelf	The region of waters surrounding the United Kingdom, in which the country claims sovereign rights
UKOOA	UK Offshore Operators Association	Trade representative for the UK offshore oil and gas industry. It works closely with companies across the entire sector, governments and other stakeholders to address key issues for the sector

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 >10 m length

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1. Introduction

Atlantic Herring *Clupea harengus* spawning grounds and spawning events appear to have a relatively wide range of seabed habitat and broader environmental requirements and parameters, 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).

There are several seabed user industry activities that are likely to interact with Atlantic Herring potential spawning habitat in English territorial waters such as: 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 should be considered as part of a cumulative impact assessment, at a suitable scale, when assessing any possible damage or deterioration to potential spawning habitat.

There are a number of marine aggregate licence renewals and new applications expected within the next 11-25 months – many of which are business critical to the operators concerned, and of great 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), MarineSpace Ltd has been engaged by the British Marine Aggregate Producers Association (BMAPA) and The Crown Estate, on behalf of the marine aggregate production companies, to facilitate the delivery of a strategic protocol to address the environmental effects of marine aggregate extraction in relation to areas that have the potential to support Atlantic Herring spawning habitat.

This method statement sets the context and rationale and outlines the methodology to enable the Environmental Impact Assessment (EIA) of marine aggregate extraction activities and associated environmental effects on Atlantic Herring potential spawning habitat. The methodology has evolved and been agreed through discussions (and a workshop) held by a quorum of marine environmental consultants (engaged in production of Environmental Statements or technical reports for marine aggregate production companies) as members of the Marine Aggregate EIA Working Group: ABPmer Ltd; ERM Ltd; Fugro EMU Ltd; MarineSpace Ltd; and Marine Ecological Surveys Ltd.

The methodology builds upon consultation and advice provided by the Marine Management Organisation (MMO) and the Regulatory Advisors Group (RAG).

The metrics, parameters and thresholds describing the environmental characteristics of Atlantic Herring potential spawning habitat, and the spatial analysis and screening exercise 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. However, it is acknowledged that the methodology in this report will be subject to periodic review, and subsequent revised versions may be released as the scientific understanding of Atlantic Herring spawning habitat preferences advances, and/or when new data become available.

The method can be applied to any area of seabed supported by British Geological Survey 1:250,000 scale seabed sediment maps, and can incorporate any species of demersal fish with ecosystem importance i.e. keystone species, where metrics and parameters for habitat preference are known or can be calculated.

2. Method

Each part of the methodology depends upon screening spatial interactions between marine aggregate application areas and the Atlantic Herring potential spawning habitat or ecological and key life-stage indicators i.e. larvae dispersion areas. The autecology of Atlantic Herring *Clupea harengus* in the North Sea and English Channel is considered, and the validity of mapping appropriate data-layers (including any limitations and confidence) is applied using a structured and tiered methodology.

The MMO and the RAG has advised (at a meeting held on 01 May 2013 (MMO, 2013)) the types of effect and effect-receptor pathways that need to be considered as part of the methodology, in order to satisfy the requirements of the EIA Directive as transposed to the MWR. *In lieu* of actual impact hypotheses to test, the environmental effects and effect-receptor pathways of potential impact on Atlantic Herring potential spawning habitat from marine aggregate dredging are associated with both the primary impact zone (PIZ) and secondary impact zone (SIZ). Direct removal of potential spawning habitat and eggs, along with physical alteration of the structure of the sediments from direct contact with the draghead, needs to be assessed. These effect-receptor pathways relate to the PIZ. Environmental effects from the sediment plumes and sediment mobilisation are considered to possibly affect *in situ* eggs through smothering, and alteration of potential spawning habitat by fining from settling sands. These effect-receptor pathways relate to the SIZ.

It is also important to note that some historic spawning grounds which currently have very little or no spawning activity can be *re-colonised* (subsequent seabed recovery from impacts and 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. Determinations regarding the potential for *re-colonisation* will also be drawn from an application's Environmental Statement (ES) regarding requirements to leave the seabed in an appropriate state (similar to pre-dredge) at the end of the term of the licence period.

The MMO and RAG has considered the environmental issues regarding entrainment of adult Atlantic Herring and larvae by the dredger draghead (MMO, 2013) and has indicated that entrainment effects are not considered significant in the context of an EIA. 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*).**

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 Secondary Impact Zone:

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

The MMO and RAG has advised that the population level effect of marine aggregate dredging on Atlantic Herring will not be required to be assessed under the MWR application process (MMO, 2013). 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 focus of this methodology is with effect pathways on habitat with the potential to support spawning activity (ICES, 2012). If the HAWG indicates that successful recruitment of larvae to the adult population becomes an issue within future population assessments then there may be a requirement to extend the assessment of effects to an adult population level. However, at the present time, the advice from the RAG and the MMO is that this is not required (MMO, 2013).

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; and
- Any effects resultant at an adult population scale from receptor-effect pathways listed in the box above (from the PIZ or the SIZ).

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, 2013).

The methodology presented in this report uses a tiered approach to map habitat and ecological space and assess appropriate receptor-exposure pathways: scoping down from population distributions at an international/national level; potential habitat at a sea/basin-scale; to potential habitat extent at an appropriate regional scale (Figure 1). This part of the methodology results in the broadscale potential spawning habitat characterisation map (the base-map) used in Step 4. Fine-scale, application area-specific screening and cumulative assessment follows, building upon the base-map – Step 4 (Section 2.2; also see Figure 5).

It is not envisaged that any additional survey data, or re-analyses of existing national or regional data, will be required to deliver the proposed methodology, above or beyond that already conducted during development of any Environmental Statement. However it is acknowledged that the methodology in this report will be subject to periodic review and subsequent revised versions may be released as the scientific understanding of Atlantic Herring spawning habitat preferences advances, and/or when new data become available.

Figure 1: Screening and mapping levels to develop Atlantic Herring potential spawning habitat characterisation.

Step 1 - Atlantic Herring populations
Screen overlap of marine aggregate regions with international/national Atlantic Herring population distribution

↓

Step 2 - UK Seas - Sediments
British Geological Survey 1:250,000 seabed sediment maps

↓

Step 3 - Regional - Sediments
Marine Aggregate Regional Environmental Asssessment and Regional Environmental Characterisation maps

↓

Step 4 - Broadscale Habitat Characterisation
Base-map

2.1. Production of the broadscale potential spawning habitat characterisation base-map

Step 1 Determination of the extent of Atlantic Herring Populations

- 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 regional seas/basin scale (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). As such, information detailing the national populations of Atlantic Herring is appropriate to set a context for site-specific assessments. The distribution of the known breeding populations of Atlantic Herring in English waters (the Orkney/Shetland, Buchan, Central North Sea and Southern North Sea populations) is considered as the highest screening layer (Figure 2).

The known spawning populations of Atlantic Herring will be mapped at an international/national seas scale. Given the distance of the Orkney/Shetland and Buchan populations from the marine aggregate extraction regions these populations will be screened out of the assessment, leaving the Central and Southern North Sea populations to be used in the screening exercise.

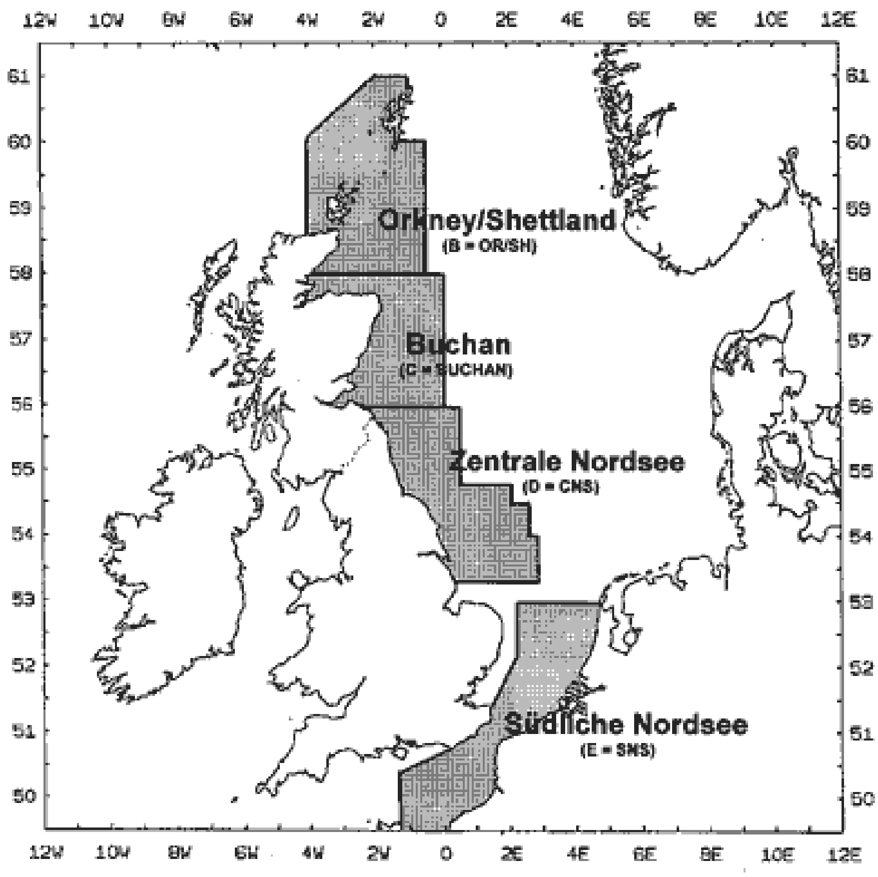
Further, considering the geographical area associated with the known populations of Atlantic Herring, and the fact that they are not associated with the Southwest Approaches, the Bristol Channel, Irish or Celtic Seas; it is proposed that the Southwest (including Bristol Channel and Severn Estuary), and Irish Sea strategic marine aggregate regions (and all marine aggregate licenses and application areas within them) are screened out of assessment at this stage of the methodology.

The Orkney/Shetland and Buchan populations are distant from the marine aggregate extraction regions; hence these populations are screened out of the assessment.

The Central North Sea and Southern North Sea populations are screened into the assessment considering their proximity to the Humber, Anglian, Outer Thames and South Coast marine aggregate regions.

Application areas in the Southwest region (Bristol Channel and Severn Estuary) and the Irish Sea are screened out of the assessment, due to the absence of Atlantic Herring populations.

Figure 2: Areas of the International Herring Larvae Survey: Orkney/Shetland, Buchan, Central North Sea and Southern North Sea. (From: The Herring Network, 2006)



Step 2 - UK Seas – Determining suitable habitat for Atlantic Herring spawning at an international/national sea/basin-scale - The initial seabed surface habitat layer is set at a biogeographic sea/basin (national) scale derived from the British Geological Survey (BGS) 1:250,000 scale seabed sediment maps (BGS, various dates. 1:250,000 seabed sediment map series). Considering the geographical location of the marine aggregate production regions in English territorial waters, the focus for this mapping layer will be the central and southern North Sea, including the English Channel.

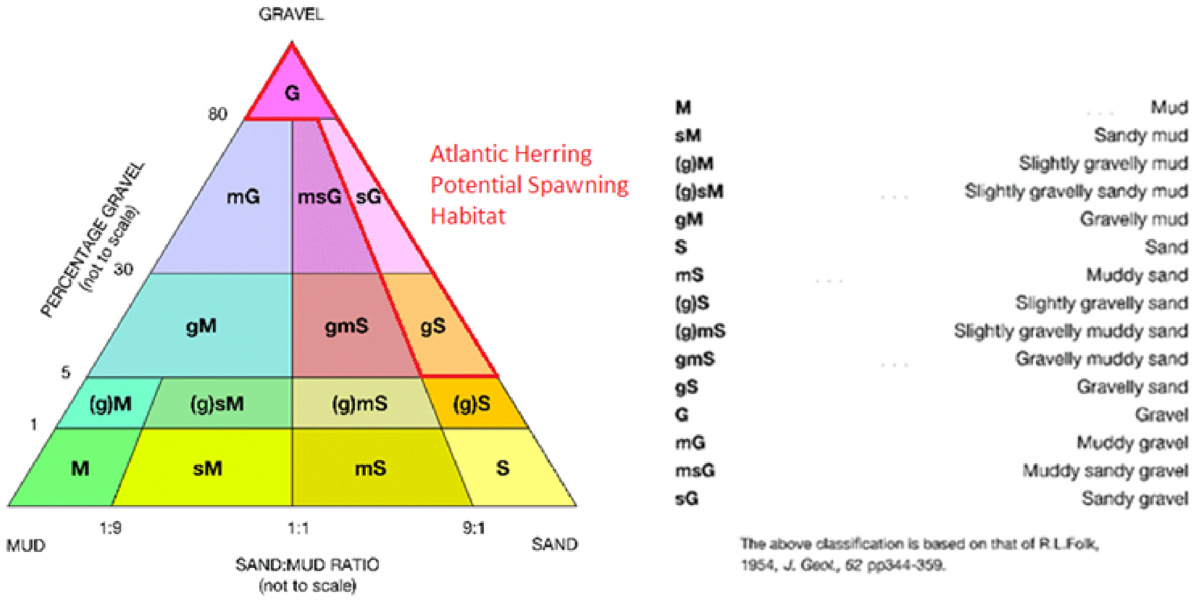
Suitable Atlantic Herring potential spawning habitat has been described in various peer review papers, technical working group reports (ICES HAWG) and grey literature (Bowers, 1980; Rankine, 1986; Aneer, 1989; Morrison *et al.*, 1991; Maravellias *et al.*, 2000; Maravellias, 2001; Mills *et al.*, 2003; Skaret *et al.*, 2003; Geffen, 2009; Payne, 2010; ECA and RPS Energy, 2010a, 2010b, 2011). In developing the methodology presented in this report, the Marine Aggregate EIA WG has reviewed the available data and classifications, liaised closely with fish ecologists and scientists at Cefas, and consulted the Marine Management Organisation (MMO). Particular attention has been given to the available parameters concerning particle size distribution data, and any ranges of preference or thresholds used previously to categorise potential spawning habitat for Atlantic Herring. Appendix A presents relevant extracts of the source material and data used in this method statement and provides an interpolation of these data using the Folk sediment triangle (Folk, 1954).

The Folk sediment classification has been used as this is also the classification scheme used to underpin the BGS 1:250,000 scale seabed sediment maps. This sediment classification has subsequently been used within the Regional Environmental Characterisation (REC) and Marine Aggregate Regional Environmental Assessment (MAREA) reports. These data are fundamental to Step 3 of the method as detailed below. Using the Folk (1954) classification enables compatibility of the final Atlantic Herring potential spawning habitat Environmental Impact Assessment (EIA) with different 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 (Appendix A) resulted in the development of the seabed surficial sediment classification presented in Figure 3. The sediment divisions with the potential to support Atlantic Herring spawning are:

- gravelly Sands – gS;
- sandy Gravels – sG; and
- Gravels - G

Figure 3: The Folk sediment triangle with representative Atlantic Herring potential spawning habitat. (Source: Folk, 1954)



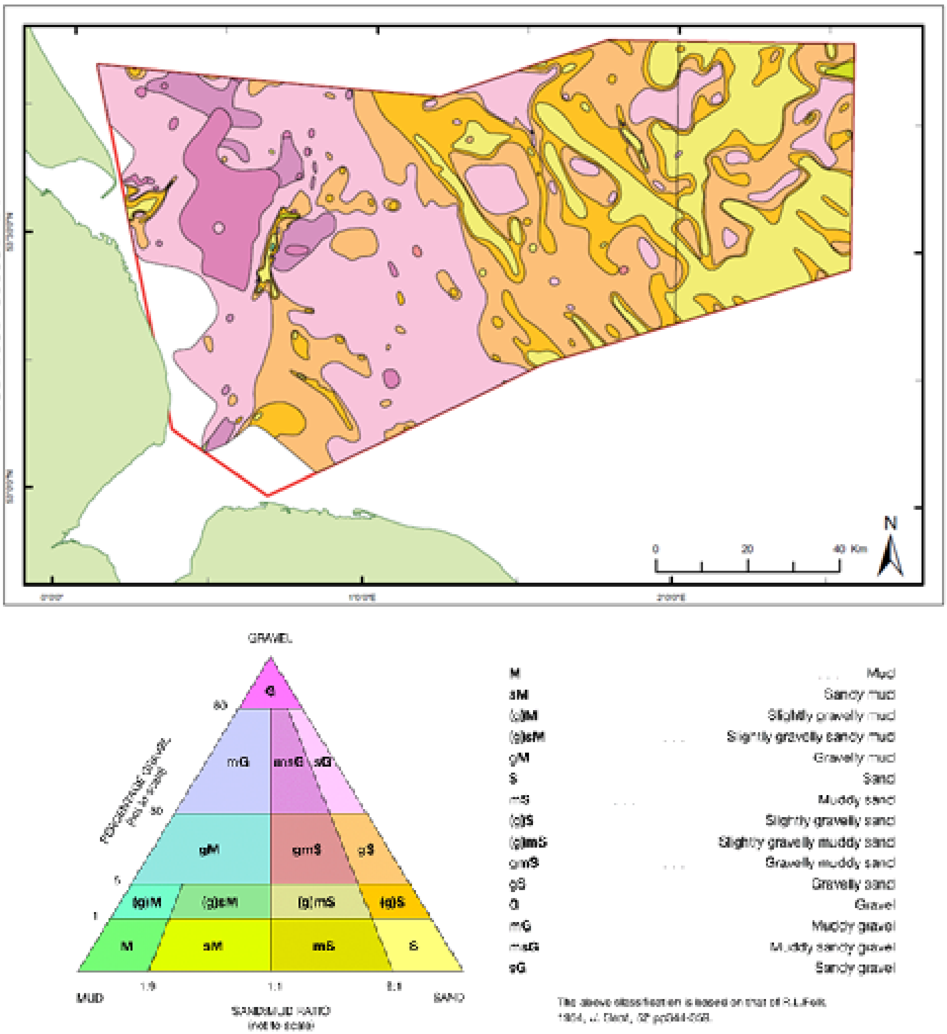
This classification, and the sediment divisions proposed, was ratified by the MMO and RAG at a meeting held on 01 May 2013 (MMO, 2013). It is important to note that the use of these sediment divisions will over-represent the full range of habitat with the potential to support Atlantic Herring spawning events. 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 3, will be used in this methodology.

Step 2 uses the BGS data (as identified above) to map the habitat with the potential to support Atlantic Herring spawning at an international/national scale. The total extent of the habitat can be identified and calculated. This value will subsequently be used when calculating the level of interaction between application areas, either alone or cumulatively, and the habitat receptor.

Step 3 - Regional – Determining the potential habitat for Atlantic Herring spawning in a regional context – Subsequently, a detailed regional-scale consideration of potential habitat using MAREA/REC maps can be made. This should be done using the Folk classification (Figure 3) and the same habitat criteria used in Step 2. These data will allow an enhanced regional-scale representation of the potential spawning habitat to be set in context of the wider seas/basin-scale resource (from Step 2).

An example of the regional seabed sediment from a REC (the Humber) is presented in Figure 4, as an indication of the data resolution available.

Figure 4: Example of seabed sediments and Folk triangle for the Humber region. (From: Tappin *et al.*, 2010)

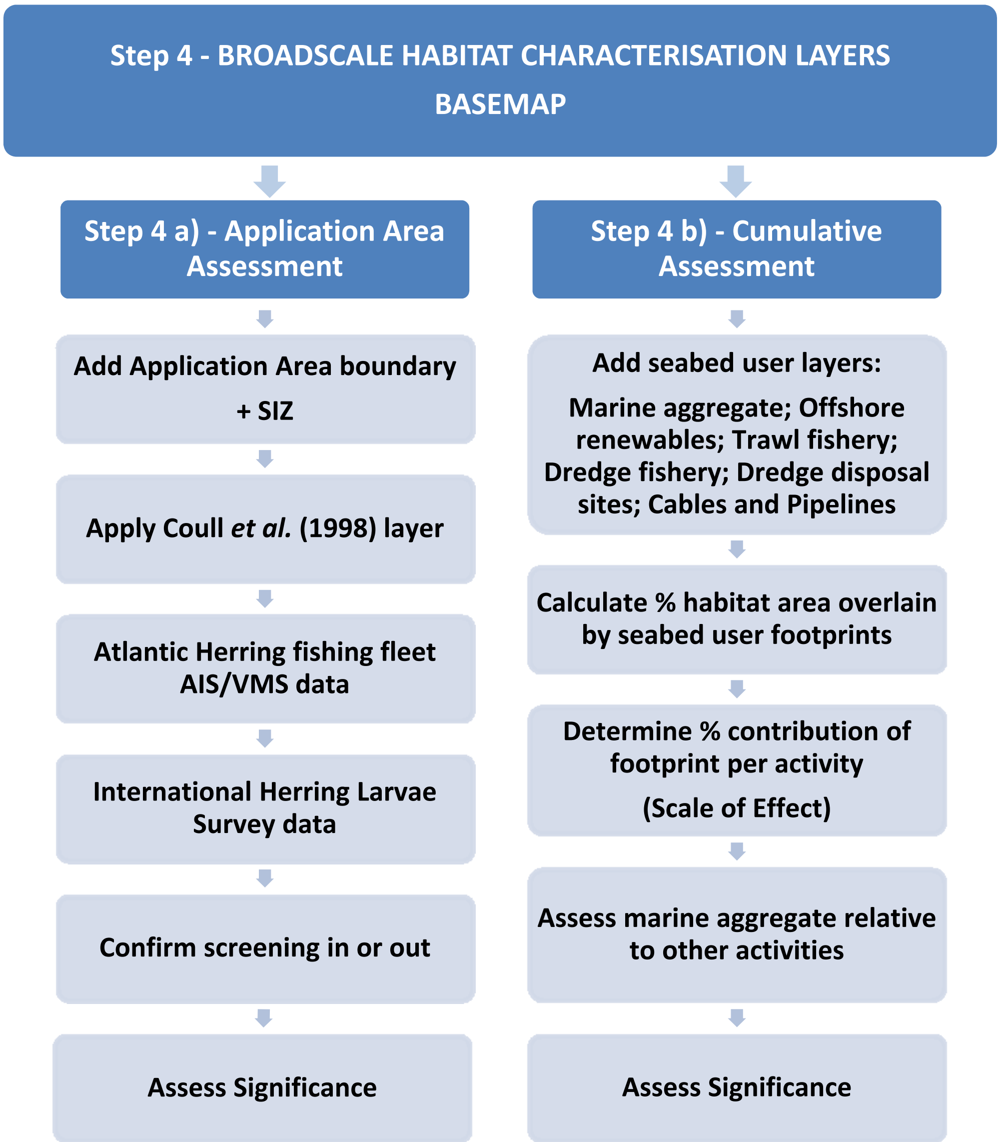


Note: Figure 4 is indicative only. Reference to the Humber REC (Tappin *et al.*, 2010) should be made to ascertain the full resolution of detail available for use in the methodology.

Steps 1-3 provide the Broadscale Habitat Characterisation Layers, the base-map, used in Step 4. A calculation of potential spawning habitat can be conducted at this stage of Step 3. All sediments which fall outside the specified classifications do not need to be considered further in this assessment. This regional extent can subsequently be related as a percentage of the total habitat available at the international/national seas-scale (as identified in Step 2). This value, along with the base-map, can be used to inform both the individual application and cumulative assessments at Steps 4a) and b) respectively, through parallel processes (Figure 5).

2.2. Production of the application area-specific maps and cumulative effects assessment

Figure 5: Screening levels to enable application area and cumulative assessment between Marine Aggregate Application Areas and Atlantic Herring potential spawning habitat.



Step 4a) – Application Area Assessment – **i. Application Area boundary and SIZ -** The first layer under the application assessment approach (Figure 5) is to map the application area boundaries and indicative SIZs. The method assumes that the boundary of the application area (the licence area) is representative of the potential PIZ i.e. an active dredge zone (ADZ) may occur anywhere within the application boundary during the period of the term applied for (15 years). The SIZ footprint is to be sourced from the ES and is likely to be either modelled from the relevant MAREA or indicative of a precautionary halo which has been tidally adjusted (derived from appropriate validated tidal prism/diamond data).

The resolution of mapping at Step 4a) is intended to allow separate pressures to be assessed at a licence-specific scale (see Section 2) e.g. application area boundary = PIZ = potential area for habitat or egg removal; SIZ sediment plume footprint = potential egg smothering zone and habitat loss/alteration through sediment fining (the addition of fine sands that will 'clog up' the sediment interstices, effectively removing the potential for the habitat to support eggs). Both the PIZ and SIZ can be used to support determinations regarding post-dredging habitat recovery and the potential for re-colonisation of these seabed areas as spawning grounds.

No application areas (and associated SIZs) are screened out at the end of Step 4a)i

Not screening out any application area at this step allows an initial mapping layer to be established, against which further screening layers may be applied through Steps 4a)ii-iv. Therefore, although an application area may not directly overlap a mapped area of spawning habitat, there may be additional data e.g. larvae survey data, which indicate exposure pathways. This enables a reasonable level of conservatism to be incorporated into the methodology and ensures that all possible exposure pathways are considered before the final screening exercise at Stage 4a)v. This rationale is also applied to Steps4a)ii-iv.

ii. Coull *et al.* (1998) layer - This data-layer draws upon the spawning ground assessment conducted by Coull *et al.* (1998), rather than the more recent assessment conducted by Ellis *et al.* (2012). Coull *et al.* (1998) considered both the known location of larvae and the relationship with suitable benthic habitat. Ellis *et al.* (2012) updated the distribution of fish larvae and information presented in Coull *et al.* (1998) but they related the mapping of this information to the ICES sub-rectangles in which they were sampled. In effect the resolution of effective mapping of these data for environmental considerations has been reduced (although it is useful as a fisheries management tool). For assessment at a regional-scale and in relation to Atlantic Herring the focussed habitat-related data from Coull *et al.* (1998) support more meaningful analysis.

The Coull *et al.* (1998) data-layer is mapped, and overlaps with any application area boundary (and associated SIZ) are identified. Comparing the available Atlantic Herring larvae distribution data (identified in Step 4a)ii) against the Atlantic Herring potential spawning sediments identified in Steps 2 and 3 increases the confidence in identifying areas of seabed which are known to have not only Atlantic Herring present, but also the potential habitat.

Due to uncertainties (low confidence) with the validity of the Coull *et al.* (1998) data-layer capturing the full range of Atlantic Herring spawning areas (due to age of and inability to acquire and reanalyse the data), application areas that fall outside the envelope are still progressed to the next stage of screening.

No application areas (and associated SIZs) are screened out at the end of Step 4a)ii

iii. Atlantic Herring fishing fleet AIS/VMS data - Given the uncertainty (low confidence) of the Coull *et al.* (1998) data-layer describing all of the Atlantic Herring potential spawning areas, this spatial layer should be enhanced where possible. The method will supplement the Coull *et al.* (1998) layer with Atlantic Herring-targeted fisheries data (where these data are available) to enhance the distribution map. The application of Automatic Identification System (AIS) and Vessel Monitoring System (VMS) data-layers may extend the boundary of the Coull *et al.* (1998) envelope. It should be noted that there are limitations in the use of AIS and VMS associated with fishing vessel size as vessels <10 m length are not required to use AIS or VMS. Therefore these data will not be fully representative of the actual fishing activity occurring within the region. Data and information presented in any specific marine aggregate licence application ES will be used to enhance Step 4a)iii where possible. Using the finest resolution of data, areas of Atlantic Herring-targeted fisheries will be mapped and considered part of the exposure pathway.

Fisheries landings data are not considered fit-for-purpose to be included in this methodology as an indication of targeted fisheries activity (due to the high uncertainty associated with linking any port of landing to the area of seabed where fish were caught). This rationale is deemed sound and supported by the MMO and RAG (MMO, 2013).

No application areas (and associated SIZs) are screened out at the end of Step 4a)iii

iv. International Herring Larvae Survey data - The next stage of the assessment is to consider 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 and southern North Sea should be used to filter the spatial extent of potential spawning habitat (MMO, 2013).

The IHLS data-layers are used to enhance the information used in Steps 4a)ii and iii, and are mapped over the preceding layers. These spatial data will be used to filter and refine the spatial extent of potential spawning habitat.

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. Significant areas of the marine aggregate Humber, Anglian and Outer Thames regions fall within the IHLS data voids. Where this is the case, other relevant data sources for Atlantic Herring larvae distribution can be used. Appropriate data available at the time of the assessment (at the pre-application stage) may be derived from published technical reports and ESs associated with other plans or projects in a consenting, planning or licensing application e.g. offshore wind farms, oil and gas pipelines etc.

No application areas (and associated SIZs) are screened out at the end of Step 4a)iv

v. Confirm screening in or out - Spatial overlap between an application area, the SIZ footprint and the data layers described above will be used to screen application areas into/out of further assessment for effects i.e. a receptor-exposure pathway exists or it does not.

A higher confidence in exposure pathway is expected where there are multiple overlaps between any single application area (or associated SIZ) and more than one of the data-layers from Steps 4a)i-iv. Sediment habitat layers (the base map, Steps 1-3) and IHLS and plan/project-specific larvae data layers (Step 4a)iv) will possess the highest confidence (and weight). Descending confidence will be ascribed to targeted fisheries data, then the Coull *et al.* (1998) layer. Individually these data-layers each hold a degree of confidence that Atlantic Herring potential spawning habitat is present, this is increased when 2 or more of these layers overlap with one another; with the highest confidence associated with a convergence of all 4 data-layers. Application areas in which 2 or more data-layers are present but with no overlap between them will also carry a high level of confidence that Atlantic Herring potential spawning habitat is present.

Application areas with no spatial overlap with any of the data layers described in Steps 4a)i-iv above will be screened out of further assessment. They will <u>not</u> have to undergo further assessment for Herring potential spawning habitat as it is demonstrated that there is no receptor-exposure pathway.

For any application area not screened out then the resolution from Step 4a) is intended to allow separate pressures to be assessed at a licence-specific scale e.g. application area boundary = PIZ = potential area for habitat removal; SIZ sediment plume footprint = potential smothering zone (habitat loss) etc.

Any application area (or associated SIZ) that overlaps with an extent of suitable potential spawning habitat identified at Step 4a)i, and which has an overlap with any of the data-layers associated with Steps 4a)ii-iv, is screened <u>into</u> further assessment i.e. there is a receptor-exposure pathway.

Step 4b) – Cumulative Assessment - The cumulative impact assessment (CIA) process allows a characterisation of the seabed footprint of relevant seabed activities (Figure 5). This step enables an assessment of the cumulative two dimensional footprints of seabed user activities that interact with the characterisation base-map produced at the end of Step 3 and used in Step 4. The percentage of area of habitat overlap and scales of effect (percentage of contribution per activity) at a regional (MAREA) scale are calculated through this stage. These values can be related to the potential spawning habitat extents from the characterisation base-map to enable a cumulative assessment.

The methodology adopts the rationale and metrics determined as fit-for-purpose for the MAREAs. The worst case scenario aligns with the rationale used to develop the MAREAs and Step 4a)i such that it is assumed that the boundary of the application area (the licence area) is representative of the potential PIZ i.e. an ADZ may occur anywhere within the application boundary during the period of the term applied for (15 years). The SIZ footprint is likely to be either modelled from the relevant MAREA or indicative of a precautionary halo which has been tidally adjusted (derived from appropriate validated tidal prism/diamond data).

The cumulative assessment will consider the footprint of all the appropriate seabed user activities at a regional-scale. The boundary of the regional-scale cumulative assessment will be the same as that indicated and mapped at Step 3 of this methodology. The relevant seabed user activities identified as interacting with potential spawning habitat are listed in Table 1 below.

The footprint of marine aggregate operations can then be ranked with the other seabed user footprints allowing determinations of scale of effect to be made. At this stage of the process there will be sufficient information to enable a cumulative assessment be conducted as part of the EIA.

The RAG has confirmed its advice that impacts on potential spawning habitat relating to any Atlantic Herring sub-population's distribution (e.g. the Downs or Banks sub-populations) will require consideration within an EIA and as part of any CIA. This consideration should be presented as a qualitative statement acknowledging that there are cumulative impacts possible outside of the MAREA study areas and within the range of sub-populations. The qualitative statements should present consideration of the seabed user activities likely to impact potential spawning habitat. These statements are required and will be supported by expert judgements on possible effects relating to each seabed user sector e.g. likely negligible habitat loss, damage or deterioration relating to the use of offshore windfarm monopiles. It is also acknowledged that certain sectors, such as marine fisheries, are much harder to parameterise due to the inter-annual variation in seabed use/impact footprint.

Table 1: Seabed user activities likely to interact with Atlantic Herring potential spawning habitat at a regional scale

Seabed User Activity	Data
Marine aggregate licence areas	Application boundary; predicted/modelled SIZ; MAREAs; RECs; The Crown Estate
Offshore renewables arrays	Array footprint; EIA worst case habitat loss predictions; The Crown Estate; Planning Inspectorate; DECC
Trawl fisheries	VMS data; IFCA plots – related to preceding 10 year data
Dredge fisheries	VMS data; IFCA plots – related to preceding 10 year data
Oil and gas pipelines	EIA worst case habitat loss predictions; Planning Inspectorate; MMO; DEAL; DECC
Telecommunication cables	Subsea Cables UK; EIA worst case habitat loss predictions; Planning Inspectorate; MMO
Dredge fines disposal sites	Cefas data with plume footprints where known

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Appendix

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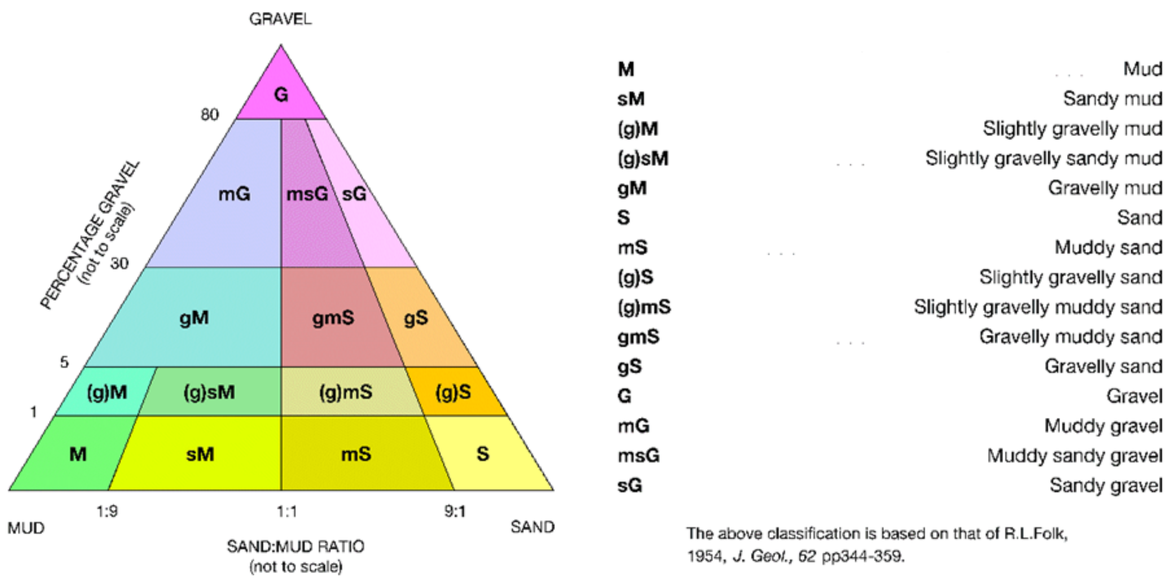
Appendix A

A sediment classification to enable the determination of Atlantic Herring *Clupea harengus* potential spawning habitat

Suitable Atlantic Herring potential spawning habitat has been described in various peer review papers, technical working group reports (ICES HAWG) and grey literature (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). In developing the methodology presented in this report these data have been reviewed with particular attention paid to the parameters concerning particle size distribution data.

Translation of the sediment data to the Folk sediment classification (Folk, 1954; Figure A1) has been conducted as this is the classification scheme used to underpin the BGS 1:250,000 scale seabed sediment maps. These maps (and sediment classification) have been used within the REC and MAREA reports. Therefore it is considered paramount that the mapping of Atlantic Herring potential spawning habitat uses the same system and data to allow compatibility and comparability with these reports.

Figure A1: The Folk sediment triangle. (Source: Folk, 1954)



Consulting the papers and reports it is evident that Atlantic Herring are considered to have a strong affinity to spawn on seabeds consisting of 'gravel' with minimal fines and good oxygenation/high levels of aeration. The following papers provide coarse environmental categorisation for herring spawning ground:

de Groot (1979)

- *Herring lay demersal eggs which adhere on stones or gravel. The eggs stick to the stones by an adhesive mucus produced in the ovary. The spawning beds are small and it is not understood what makes the herring select one locality rather than another*.
- *Bolster and Bridget (1957) described a typical Downs herring spawning area in the English Channel (Sandettie). They found that spawn was generally attached to flints, 2.5--25 cm in length, where these occurred over gravel. The heaviest concentration was found within an area 3.5 km long and 400 m wide. The long axis of this narrow strip lay in line with the main direction of the tidal current. Parrish* et al. *(1959) surveyed a spawning bed in the Firth of Clyde and found that the boundary of the egg patch coincided with a change from gravel and small stones to large stones and rocks.*
- *Hemmings (1965) also made underwater observations on a patch of herring spawn in the Firth of Clyde (Ballantrae Bank). He observed the herring spawn lying as a carpet on fairly coarse gravel of uniform size. Also that herring select not only the right size of gravel on which to deposit their eggs, but also the crest of a ridge instead of the hollows*.
- *Dorel and Maucorps (1976) made an attempt to correlate the sedimentologic characteristics of the substrate with herring catches and hydrological data of the Downs herring spawning grounds in the Channel and Seine Bay. Despite the lack of herring eggs among the dredged sediments during their survey, they could distinguish three spawning areas. The average composition of the sediment was boulders 42.2%, gravel 34.0% and sand 23.8%. On Fig. 2 is shown the positions of capture of spawning herring based on all available data from Dutch vessels over the period 1955--1973. If compared with Fig.3 showing the gravel deposits of the North Sea, the overlap is a striking feature.*
- *From the above-given data on herring spawning grounds and their nature, it is clear that essential are a high bottom velocity (1 m/sec), no silt and a high concentration of gravel, with or without seaweed, for the eggs to adhere to.*

de Groot (1980)

- *Deposits its eggs on the sea bed attaching them to gravelly material.*
- *Iles and Caddy (1972) made an underwater survey of herring spawning on the Georges Bank, Boston, USA. They located the egg beds on a flat gravel-covered plain at a depth of 50 m. The gravel was rounded, varying in particle size from0.5-5 cm to stones from 8-15 cm and boulders.*

de Groot (1986)

- *It is still not known why herring select a specific spawning ground.*
- *Gravel to be left on the seabed to enable herring to spawn.*

de Groot (1996)

- *Also re-deposition of fines from the plumes, which may extend beyond the actual dredging area, may smother eggs laid on the bottom*

- *Herring lay demersal eggs which adhere on stones or gravel. The eggs stick to the stones by an adhesive mucus produced in the ovary. The spawning beds are small and it is not understood what makes the herring select one locality rather than another.*

Heath *et al.* (1997)

- *Herring eggs are laid and adhere strongly to stones and gravel on the seabed.*

Maravelias *et al.* (2000)

- *Herring is the only marine clupeoid which lays demersal eggs. Eggs are laid on gravel areas on the seabed (Blaxter, 1990).*

Geffen (2009)

- *The depth and substratum of the spawning beds may vary to some extent but, for the most part, herring spawn coastally and on offshore banks, and deposit their eggs on gravel or rocks.*

Nash *et al.* (2009)

- *North Sea herring eggs are spawned on gravel beds thus leading to spatial constraints on spawning*.

HAWG (2012)

- *The spawning grounds in the southern North Sea are* 1 [*located in the beds of rivers which existed in geological times*] *and some groups of spring spawning herring still spawn in very shallow in-shore waters and estuaries.* 2 [*Spawning typically occurs on coarse gravel (0.5-5 cm) to stone (8-15 cm) substrates*] *and often on the crest of a ridge rather than hollows*.
- *For example, in a spawning area in the English Channel, eggs were found attached to flints 2.5-25 cm in length, where these occurred in gravel, over a 3.5 km by 400m wide strip.*

Therefore in order to define suitable herring spawning habitat with regard to PSA data, Cefas fish ecologists and scientists advised a high gravel content (majority of the sediment being gravel), with minimal fines and good oxygenation for herring spawning ground.

Sedimentary analysis routinely separates samples based on the particle size of the component grains. The resulting size fractions have been described and standardised by Wentworth (1922) and are the accepted form of reporting the particle size distribution of sediments (Table A1). Folk (1954) produced a matrix to describe seabed sediments based upon the ratio of Sand to Mud in relation to the percentage Gravel within a sample (Figure A1). The British Geological Survey (BGS) has utilised the Folk (1954) classifications for mapping the seabed and cross referenced with the Wentworth scale for the divisions between Mud, Sand and Gravel (Table A2). This has become the standard particle size arrangement utilised in the broadscale 1:250,000 BGS scale seabed sediment maps and is widely reported elsewhere.

Table A1: Wentworth particle size descriptions. (From: Wentworth, 1922)

Particle size (mm)	Size terms (after Wentworth, 1922)	
>64	Cobbles	
64-32	Pebbles	very coarse
32-16		coarse
16-8		medium
8-4		fine
4-2		very fine
2-1	Sand	very coarse
1-0.5		coarse
0.5-0.25		medium
0.25-0.125		fine
0.125-0.062		very fine
0.062-0.031	Silt	coarse
0.031-0.016		medium
0.016-0.008		fine
0.008-0.004		very fine
<0.004	Clay	

Table A2: The British Geological Society division of Folk sediment classifications based upon the Wentworth (1922) scale. (Source: Wentworth, 1922; Folk, 1954)

Particle size (mm)	Size terms (after Wentworth, 1922)		Size terms (after Folk, 1954)
>64	Cobbles		Gravel
64-32	Pebbles	very coarse	
32-16		coarse	
16-8		medium	
8-4		fine	
4-2		very fine	
2-1	Sand	very coarse	Sand
1-0.5		coarse	
0.5-0.25		medium	
0.25-0.125		fine	
0.125-0.062		very fine	
0.062-0.031	Silt	coarse	Mud
0.031-0.016		medium	
0.016-0.008		fine	
0.008-0.004		very fine	
<0.004	Clay		

The review and analysis of the source data for potential spawning habitat resulted in the overlay of the seabed surficial sediment classification presented in Figure A2. The over-riding physical parameters are interpreted (from Cefas advice and source material, translated to the Folk classification, Table A2) such that:

- High gravel content (majority of the sediment being gravel) = >50% gravel; and
- Minimal mud content = <5% mud (silt and clay particles < 63 µm).

The particle size thresholds listed above also follow the rationale and thresholds used in the East Channel Regional assessment of Atlantic Herring spawning habitat (ECA and RPS, 2010a, 2010b, 2011). The sediment divisions with the potential to support Atlantic Herring spawning have been classified according to the 'preference' that the fish appear to make, as drawn from the data. These use a similar nomenclature to that used by Greenstreet *et al.* (2010) when describing and classifying sandeel 'preferred' habitat. The particle size thresholds, Folk sediment units and 'preference' of habitat to support habitat are presented in Table A3.

Table A3: The partition of Atlantic Herring 'preferred' spawning habitat.

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

The translation of the sediment particle distribution from Tables A1 and A2 and Figure A2 is to a degree arbitrary, considering the wide range of habitat parameters in the literature reviewed. Therefore the final potential spawning habitat classification has been extrapolated to each of the wider over-arching Folk sediment units as presented in Figure A3 (and Figure 3 in the main body of the report). This has resulted in the following Folk sediment divisions/units being considered as 'preferable' (equivalent to prime, sub-prime and suitable) potential spawning habitat for Atlantic Herring:

- gravelly sands – gS;
- sandy Gravels – sG; and
- Gravels - G

These Folk sediment units are mapped as Atlantic Herring potential spawning habitat in the methodology presented in this report to create the base map (Steps 2 and 3) and subsequently used in the screening exercise (Step 4).

As comparison between Figure A2 and Figure A3 shows, the use of these sediment divisions will over-represent the full range of habitat with the potential to support Atlantic Herring spawning events due to the percentage of fines 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% mud (<63 µm) is not possible. The MMO and RAG have advised that such an exercise is beyond the requirements of any specific EIA (as required under the MWR) (MMO meeting note, 2013).

Figure A2: The Folk sediment triangle with partition of Atlantic Herring 'preferred' spawning habitat. (Source: Folk, 1954)

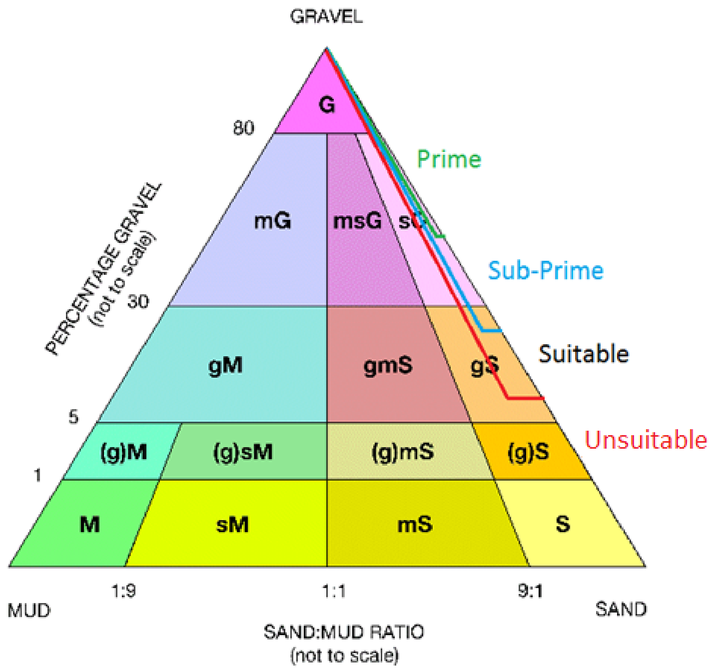
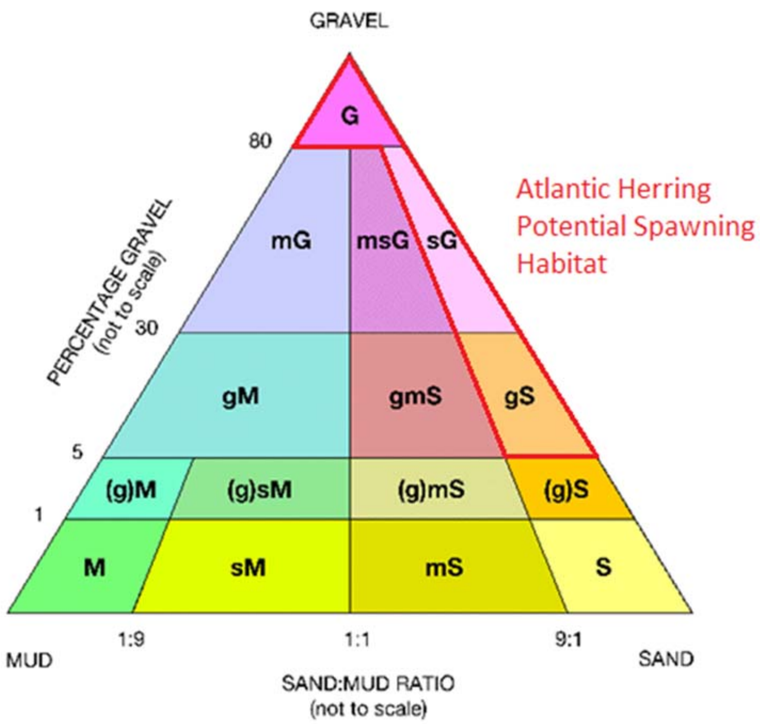


Figure A3: The Folk sediment triangle with Atlantic Herring potential spawning habitat used in the methodology. (Source: Folk, 1954)



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Appendix B: Confidence Assessment Protocol and Methodology Version 6

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Mapping the Potential for Atlantic Herring Spawning Habitat and Sandeel Habitat:

Confidence Assessment Protocol and Methodology (Version 6)

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ABP marine environmental research Limited, Environmental Resource Management Limited, Fugro EMU Limited, MarineSpace Limited, and Marine Ecological Surveys Limited have been commissioned by HaskoningDHV UK Limited, a company of Royal HaskoningDHV, acting in its capacity as Minerals and Infrastructure Managing Agent for The Crown Estate, on behalf of: British Marine Aggregate Producers Association; Boskalis Westminster Limited; Britannia Aggregates Limited; CEMEX UK Marine Limited; DEME Building Materials NV; Hanson Aggregates Marine Limited; Sea Aggregates Limited; Tarmac Marine Dredging Limited; and Volker Dredging Limited; to conduct regional cumulative impact assessments (CIAs) of marine aggregate application areas with seabed that has the potential to be used as: spawning habitat by Atlantic Herring *Clupea harengus*; and as habitat supporting sandeel species; *Ammodytes marinus*, *A. tobianus*, *Gymnammodytes semisquamatus, Hyperoplus lanceolatus* and *H. immaculatus*.

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1. Overview

1.1. Introduction

Confidence in the mapped Atlantic Herring potential spawning habitat and sandeel habitat or the '*Herring and sandeel indicator layers*' is required for all the exposure pathways (licence area + impact zone). Any confidence assessment that is informed through multiple data layers needs firstly to assess the confidence in each layer; and secondly to assess the combined confidence. The individual layers may either have spatially uniform or variable confidence, depending on the underlying data.

The rationale and methodology used in this report and applied to the regional Cumulative Impacts Assessments (CIAs), detailed in Reach *et al.* (2103) and Latto *et al.* (2103) have been discussed with Cefas and agreed (MMO, 2013).

1.2. Datasets Considered

The spatial datasets considered in the confidence assessment to inform the location of Atlantic Herring potential spawning grounds, and habitat likely to support sandeel, include:

- Substrate Folk Classification: British Geological Survey (BGS);
- Substrate Folk Classification: Marine Aggregate Regional Environmental Assessment (MAREA);
- Substrate Folk Classification: Regional Environmental Characterisation (REC);
- Fishing Fleet: Vessel Monitoring Systems (VMS);
- Fishing Fleet: Marine Management Organisation (MMO) Sightings;
- Fishing Fleet: Inshore Fisheries and Conservation Authorities (IFCA) Sightings;
- Spawning Grounds: Eastern Sea Fisheries Joint Committee (ESFJC);
- Spawning Grounds: Coull *et al.* (1998); and
- Spawning Grounds (Herring only): International Herring Larvae Surveys (IHLS)

In all cases, except International Herring Larvae Surveys (IHLS) which only target Atlantic Herring, the data inform the potential location of spawning grounds for Atlantic Herring and sandeel habitat. For any one data source, e.g. Eastern Sea Fisheries Joint Committee (ESFJC), the confidence assessments detailed below are generally the same for both Atlantic Herring and sandeel, as the same methods have been used in data collation/processing. However, in the case of seabed sediment data, the confidence does differ, as outlined below.

All datasets needed to be in a polygon format, as opposed to point data, as this allows them to be combined and give an overall assessment.

1.3. Datasets Omitted

Whilst there was some potential in interpolating the Marine Management Organisation (MMO) sightings data to form area (polygon) data, this dataset was omitted after plotting the relevant gear types (as detailed below for Vessel Monitoring System (VMS)) and comparing against VMS data. This indicated that the VMS data already show the relevant gear type in the same locations as presented by the MMO sightings, except in a very few cases that were not considered significant.

The Inshore and Fisheries Conservation Authority (IFCA) dataset has also been excluded as the full resolution (all IFCAs) dataset was not supplied within the required timescales.

The REC substrate 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 (Humber, East Anglia, South Coast RECs); and the Marine Aggregate Regional Environmental Assessments (MAREAs) include REC data Therefore use of the REC data would result in duplication of data.

1.4. Confidence Test Method

1.4.1. Confidence in the Data

Following review of various approaches used to date, including MESH[1], UKSeaMap[2], the MMO's approach (MMO, 2013), a scoring proforma has been developed to apply to confidence assessments as shown below (Table 1.1). This was adopted where there were no supporting spatial data to inform spatial variation in confidence.

The first five parameters (method, vintage, positioning, resolution, quality standards) are concerned with the data themselves, i.e. how confident is the Marine Aggregate EIA WG in the data being as described?

Note that 'spatial coverage' has not been assessed but instead the resolution 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.

[1] http://www.searchmesh.net/default.aspx?page=1635
[2] http://jncc.defra.gov.uk/pdf/UKSeaMap2010_TechnicalReport_7_ConfidenceExternalReview.pdf

Table 1.1: 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
Resolution	Resolution of the data in terms of what is included, density of points, time series length and interval, 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

1.4.2. 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.

1.4.3. 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 (MMO, 2013).

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. This is addressed separately in Section 2.1 and 2.3 below.

1.4.4. Scoring

For each parameter or confidence test detailed above (i.e. that contributes to the data layer's overall score), a score between 0 and 3 is assigned, where 0 = unknown and 3 = high confidence. However for the indicator of spawning (final parameter in table above), 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 1.2: 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. This is illustrated further in Section 3.

1.4.5. Confidence in the seabed 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 (Appendix A and Addendum).

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 of MarineSpace Ltd *et al.*, 2013a; Reach *et al.*, 2013). This field is termed 'Folk category indicates marginal/preferred habitat[3]' 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 data. Therefore the matrix is scored from 0 to 2. As detailed in Section 1.4.4 above, where scoring the indicator for spawning, a zero score does not imply 'unknown', but 'very low' instead.

Each of the two parameters are scored separately from 0 to 2 (very low to medium); then the two are combined as shown in the matrix (Table 1.3).

Table 1.3: Generic matrix for habitat sediment type confidence used in the Confidence Assessment Protocol and Methodology.

	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)

[3] Whilst acknowledging that seabed sediment class is only one physical parameter that contributes to the overall habitat requirements for Atlantic Herring with the potential to support spawning e.g. oxygenation, nearbed transport rates, micro-scale seabed morphological features etc.

As per the method statement for Atlantic Herring, of the three Folk categories that contribute to potential spawning habitat (Gravel (G), sandy Gravel (sG) and gravelly Sand (gS)), all of these over-represent the habitat sediment divisions. This reduces the confidence. Therefore the matrix results are as follows in Table 1.4:

Table 1.4: Matrix for Atlantic Herring potential spawning habitat sediment type confidence scoring used in the Confidence Assessment Protocol and Methodology.

	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

Similarly the sandeel preferred and marginal habitat sediment classification is represented in Latto *et al.* (2013) and used within the regional CIAs. This is detailed in Section 2.1.2 below with the rationale drawn from Latto *et al.* (2013) and also the Appendix A of MarineSpace Ltd *et al.* (2013b).

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 in relation to marginal habitat presence and magnitude of effects will then be considered within the application's EIA.

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

The IHLS has the highest confidence (final score of 5 – see Section 2.6) 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 in the interpolated IHLS map, 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.

As mentioned previously, the IHLS data represents 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.

2. Individual Layers' Confidence Assessment

2.1. Habitat from BGS Folk classes (substrate)

2.1.1. Confidence in the BGS Data

The confidence in substrate needs to be assessed for both the data themselves and the level of confidence in it acting as an indicator of potential spawning habitat for Atlantic Herring and sandeel. The confidence in the data is scored and justified within the first five parameters in the table below. As these first five parameters are concerned solely with the data, they are identically scored for Atlantic Herring and sandeel. No spatial variation is provided for the confidence in the substrate data (i.e. the data themselves).

Table 2.1: British Geological Survey Folk Map Confidence Scores

Confidence test	Score*	Rationale - Please explain scoring with reference to all considerations
Method	2	This is assumed in absence of BGS input. The BGS substrate map and Folk classes are interpolated from PSA samples, multibeam and seismic surveys. Confidence for BGS SBS V3 has been inferred from the confidence provided by UKSeaMap (2010) as this is all that is available to assess within the timeframes of the Atlantic Herring and sandeel project. However BGS SBS V2 was used in UKSeaMap and also UKSeaMap used an additional 3 datasets: the hard substrata layer (Gafeira *et al.*, 2010); the Water Framework Directive (WFD) typology layer (Rogers *et al.*, 2003); and the NOC deep sea sediment layer (Jacobs and Porritt, 2009). Minor gaps between the substrate layer and the mean low water mark were subsequently filled using data from Marine Nature Conservation Review surveys. These survey methods are unknown, but are clearly approved for use by BGS in national mapping.
Vintage	1	This is assumed in absence of BGS input. BGS data are often old (>10 years).
Positioning	3	This is assumed in absence of BGS input. All locations are likely to be provided through accurate GPS systems.
Resolution	3	This is assumed in absence of BGS input. The density of survey data informs confidence in interpolation. Whilst the dataset uses a variety of data types (remote sensing, PSA), a case study example of PSA density has been assessed for the Humber REC, which shows a map of legacy data in the report. The data density is good.
Quality Standards	2	This is assumed in absence of BGS input. Data are clearly approved for use by BGS in national mapping.
Spawning Indicator	Herring = 1 or 0 sandeel = 2 or 0	See matrices below. Varies by Folk class category, Folk class boundary representation; and varies between Atlantic Herring and sandeel.

2.1.2. Confidence in the BGS Data Indicating Spawning Grounds

As detailed in the full reports, Atlantic Herring is known to prefer Gravel and sandy Gravel; and also have a marginal preference for habitats of gravelly Sand. Sandeel are known to prefer Sand, slightly gravelly Sand and gravelly Sand; and also to have a marginal habitat preference within sandy Gravel. Therefore the Folk sediment class provides a spatially variable indicator of spawning and habitat potential and hence level of confidence.

However the level of confidence in the Folk classes indicating potential spawning habitat needs to consider two variables. First, it needs to consider the confidence that the Folk category contains the correct seabed sediment, e.g. there is more confidence in Gravel indicating Atlantic Herring potential spawning habitat (hence the 'preferred habitat'), than gravelly Sand (the 'marginal habitat'). This is termed 'Folk category indicates marginal/preferred habitat' in the matrix below.

Secondly, it needs to consider whether the Folk class boundaries, i.e. the upper and lower limits of each of Gravel, Sand and Mud, are defined in the correct form to delineate the potential spawning habitat for Atlantic Herring or habitat used by sandeel, e.g. the Folk category Gravel contains sediment types outside of the preferred range for Atlantic Herring spawning and therefore has a lower confidence than, for example, the Sand class for sandeel which is suitably defined, i.e. sandeel preferred habitat is within the whole of the Sand class. This is termed 'Folk category over represents/correctly represents' in the matrix below. These considerations are illustrated fully in the main report.

Due to these two factors, a matrix has been developed to assess confidence in the BGS data indicating Atlantic Herring potential spawning habitat and sandeel habitat, as shown below. Normally such matrices are provided for parameters scored from low to high, or numerically, e.g. from 1 to 3. However, in this case, it is never possible that the BGS data can indicate potential spawning habitat with high confidence as it is only an indicator, i.e. direct measurements of spawning, such as IHLS, carry much greater confidence. Therefore the matrix is scored from 0 to 2. As detailed above, where scoring the indicator for spawning, a zero score does not imply 'unknown', but 'very low' instead.

Therefore, 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 in Table 2.2.

Table 2.2: Generic matrix for habitat sediment type confidence used in the Confidence Assessment Protocol and Methodology.

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

Atlantic Herring

As per the method statement for Atlantic Herring, all of the three Folk categories that represent potential spawning habitat for Herring (Gravel, sandy Gravel and gravelly Sand) over-represent the categories. This reduces the confidence. Also the greatest preference for habitat is at the gravelly end of the scale. This increases the confidence. Therefore the results are as follows in the matrix in Table 2.3.

Table 2.3: Matrix for Atlantic Herring potential spawning habitat sediment type confidence scoring used in the Confidence Assessment Protocol and Methodology.

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

Sandeel

As per the method statement for sandeel, of the four Folk categories that represent potential habitat for sandeel (sandy Gravel, gravelly Sand, slightly gravelly Sand and Sand), one of these over-represents the category: sandy Gravel. This reduces the confidence. Also the greatest preference for habitat is at the sandy end of the scale. This increases the confidence. Therefore the matrix results are as follows in Table 2.4.

Table 2.4: Matrix for sandeel habitat sediment type confidence scoring used in the Confidence Assessment Protocol and Methodology.

	Folk category over represents = 0 (very low)	Folk category represents correctly = 2 (medium)
Folk category indicates marginal habitat = 0 (very low)	sG = 0 (very low)	N/A
Folk category indicates preferred habitat = 2 (medium)	N/A	gS, (g)S, S = 2 (medium)

2.2. Habitat from MAREA Folk classes (substrate)

2.2.1. Confidence in the MAREA Data

The confidence scoring of the MAREA data is provided in the first five categories of the table below. The data density used to underpin both the BGS and MAREA sediment layers is relatively similar, although with a slight bias to marine aggregate areas in the MAREA data, as expected. However as new licences may be in areas not focused on during the MAREA, the resolution is considered to have the same level of confidence as BGS.

Table 2.5: Marine Aggregate Regional Environmental Assessment Folk Map Confidence Scores

Confidence test	Score*	Rationale - Please explain scoring with reference to all considerations
Method	2	Method of data collection varies between projects.
Vintage	3	All regional MAREA data collected in the last 10 years, some regions more recently than others.
Positioning	3	Accurate GPS recording of locations
Resolution	3	Density of sampling within each MAREA region is greatest in the vicinity of licence areas. As the project will use licence areas, the score reflects this.
Quality Standards	2	This is assumed in absence of information in report. Data are approved by MMO and RAG for use by BMAPA and supplied by professionals.
Spawning Indicator	Herring = 1 or 0 Sandeel = 2 or 0	See matrices below. Varies by Folk class category, Folk class boundary representation; and varies for Atlantic Herring and sandeel.

2.2.2. Confidence in the MAREA Data Indicating Spawning Grounds

The MAREA dataset has been addressed in the same way as per the BGS Folk class layer. However there are some discrepancies in the presentation of certain sediment classes that affect the way these data may be used to assess Atlantic Herring potential spawning habitat and habitat used by sandeel.

First, the MAREA datasets, whilst mostly complying with the Folk classification, sometimes combine two classes into one.

- The Thames MAREA has grouped sandy Gravel and gravelly Sand as a single mapping unit. However these two sediment classes delineate the threshold between marginal and preferred habitat for both Atlantic Herring and sandeel.
- The South Coast MAREA has grouped Gravel and sandy Gravel as a single mapping unit. However, only one of these two sediment classes, sandy Gravel, is suitable to be used as an indicator for sandeel (marginal habitat).
- In some cases even coarser groupings are made, collating more than two Folk classes, using a classification system that aligns with EUNIS (European Nature Information System). In UKSeaMap 2010, the four EUNIS broad sediment classes of coarse sediment, mixed sediment, sand and mud are assigned to the different Folk categories. (The allocation made in UKSeaMap 2010 is considered standard practice in the UK.) This groups three sediment classes within coarse sediment: Gravel, sandy Gravel and gravelly Sand. Whilst all these three Folk classes within coarse sediment are contained within the Atlantic Herring potential spawning habitat, the threshold between marginal and preferred habitat lies between two of these (sG and G). Also, for sandeel, the coarse sediment category includes an additional Folk class, Gravel, which is not a potential spawning habitat for sandeel.

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

Note: The MAREA data were supplied with the shapefiles clipped to each of preferred and marginal habitats, for each of Atlantic Herring and sandeel. Due to the issue of combined Folk sediment classes as noted above (for the Outer Thames and South Coast regions), this resulted in both the preferred and marginal shapefiles showing the same area of potential habitat, e.g. the combined Gravel and sandy Gravel class was present in each shapefile even though part of the sediment class mapped did not conform to the habitat parameters for the shapefile in question. In effect the shapefiles over-represent the preferred or marginal habitat and this misrepresentation is present in both shapefiles. Therefore, at the Outer Thames regional level (for both Atlantic Herring and sandeel) and at the South Coast (for sandeel) double-accounting of seabed occurs with an area incorrectly representing both marginal and preferred habitat which cannot occur in the real world; as the two layers are mutually exclusive. In the confidence layers produced, no overlap was allowed and any overlap is removed by taking the lower class, i.e. marginal.

The second difference with BGS data is in the overlapping of data between adjoining MAREA regions e.g. there can be some disagreement in interpreted Folk classes at overlapping MAREA locations. Again, the lowest confidence approach has been taken, e.g. if one MAREA predicts gravelly Sand whereas the other predicts Gravel, then in the case of Atlantic Herring, the lowest confidence (for gravelly Sand) is adopted.

2.3. Coull *et al.* (1998)

2.3.1. Confidence in the Coull *et al.* (1998) Data

The scores for the confidence in the Coull *et al.* (1998) data are provided in the first five parameters of the table below. There were no spatially varying parameters that could be used to inform confidence in the maps provided in the report (and no GIS available).

Table 2.6: Coull *et al.* (1998) Spawning Grounds Confidence Scores

Confidence test	Score	Rationale
Method	1	Data are based on collated distribution of eggs, larvae, young and commercially sized fish, seabed sediments, and acoustic visualisation techniques. However, no detail is provided as to the source of these data, their robustness, or age, and it is not clear how the maps have actually been compiled. However, it is stated that the data are sourced from reputable Government agencies (Cefas, FRS) which would indicate suitable techniques were used, and the paper from which the maps are taken has been published and referred to in subsequent publications (e.g. Ellis *et al.*, 2010).
Vintage	1	Report published 1998 and so data are at least 15 years old and patterns in spawning may have changed - it is stated that the map should not be seen as a rigid, unchanging description of presence or absence. It is not stated what range of data have been used in the report, or when they are from.
Positioning	1	As no method has been provided for how the boundary of spawning areas was produced, accuracy is not known.
Resolution	2	Full UK coverage is provided at relatively fine scale (although with limitations, as described above). The report states that the maps represent the widest known distribution given current knowledge (1998). It does not specify what area is covered but maps appear to cover all of the North Sea and English Channel (as relevant to this project). The resolution is down-graded however, due to a lack of coverage along the English south coast. There is no information provided on density of points to inform the maps. As noted above, it is stated that the map should not be seen as a rigid, unchanging description of presence or absence.
Quality Standards	0	No evidence of any quality standards.
Spawning Indicator	2	It is possible that no inference between actual data points is made and is direct mapping of spawning. However methods do not qualify this and only indicate so cannot be 100% sure.

2.3.3. Confidence in the Coull *et al.* (1998) Data Indicating Spawning Grounds

Whilst the Coull *et al.* (1998) layer has specifically been developed to show spawning grounds, the methods reported do not detail what types of data were used, lowering the confidence.

2.4. VMS Fishing Fleet

2.4.1. Confidence in the VMS Data

As outlined in the table below, the confidence in the VMS data (first five parameters in table) is strong, owing to the statutory requirement and standardised equipment to comply with domestic legislation. There are no parameters provided in the GIS that can be used to inform spatial variation in confidence, so the VMS data confidence is uniform.

Table 2.7: Vessel Monitoring System Gear Type Confidence Scores

Confidence test	Score	Rational
Method	3	Vessel monitoring systems (VMS) are satellite-based systems used in commercial fishing to allow environmental and fisheries regulatory organizations to monitor the position, time at a position, and course and speed of fishing vessels. VMS data are collected through specialist electronic equipment. All vessels over 12 m must operate VMS when at sea, to comply with EU law. The technical requirement for these devices is stated in the Commission Implementing Regulation (EU) which lays down detailed rules for the implementation of Council Regulation. Therefore the method of data collection is of a high standard
Vintage	3	2006-2012 up to date data.
Positioning	3	Positional data extracted from GPS-Derived Vessel Monitoring Data. These recordings are made using tamper-proof technology with an error less than 500 m at 99% confidence.
Resolution	2	The entire North Sea and English Channel are covered by VMS data. VMS systems have been compulsory since 2004 for >18 m vessels, with increasing control for smaller vessels until 2011 (>12 m). Therefore data resolution increases over time as the smaller vessels become included. No vessels <12 m including, for instance, the inshore under 10 m fisheries fleet are included in this data set.
Quality Standards	3	Data reviewed by the MMO and accompanied by MEDIN standard metadata.
Spawning Indicator	0	VMS data are split into demersal gear types and pelagic gears. The pelagic gears (industrial trawler, pelagic side trawler, pelagic stern trawler) target adult Atlantic Herring, as well as many other species; and therefore provide a low confidence indicator to spawning grounds and habitat. Whilst Atlantic Herring are highly mobile species, Atlantic Herring fishing generally occurs close to, and during, the spawning season and therefore there is some indication of the location of spawning grounds, albeit with very low confidence due to the targeting of other species. The demersal gears target sandeel as well as many other species; and therefore also provide a low confidence indicator to habitat. Sandeels are not very mobile and therefore the time of fishing activity within the year is not important, and any fishing activity with these gear types may therefore target sandeels. With the exception of industrial trawlers (Sandeeler) these gears are likely to be targeting a number of species and may not be targeting Atlantic Herring or sandeel at all. Therefore with the exception of Sandeelers there is low confidence in this data.

2.4.2. Confidence in the VMS Data Indicating Spawning Grounds

VMS data only provide differentiation between fishing locations by gear types, and therefore it is the gear types that have been used to inform spawning areas. As one gear type will target a number of species and not just Atlantic Herring or sandeel, the probability of it informing spawning grounds or habitat is very low. A full justification is provided in the table above. However, in summary, pelagic gears are an indicator of Atlantic Herring spawning areas; and demersal gears are an indicator of sandeel habitat as well as an indication of habitat damage and/or deterioration pressure footprints.

2.5. ESFJC fishing boundaries

2.5.1. Confidence in the ECFJC Data

The Eastern Sea Fisheries Joint Committee (ESFJC) (now the Eastern IFCA) GIS dataset specifically provides boundaries of Atlantic Herring, Sprat, and sandeel regions, together with month and season present, fishing gear used, and importance of any area to the fishers (targeted fishery vs. occasional) (amongst other variables). Whilst there were no variables suitable to determine spatial variation in confidence, the uniform confidence assessment for this layer is provided in the first five parameters of the table below.

Table 2.8: Eastern Sea Fisheries Joint Committee Spawning Grounds Confidence Scores

Confidence test	Score	Rationale
Method	2	These layers are the output of the Eastern Sea Fisheries Joint Committee's Fisheries Mapping Project, which has aimed to describe - using best available data and fishermen's knowledge - the extent of the main fisheries within the ESFJC District. Outputs are produced using the best available data and fishermen's knowledge, however best available data is not defined and a caveat is given detailing that the data should only be considered illustrative.
Vintage	2	2010 data - these data are illustrative of the types of activity within the District.
Positioning	1	Data produced using the best available data and fishermen's knowledge. Best available data is not defined and a caveat is given detailing that the data should be considered illustrative only.
Resolution	1	Unknown how many data sources were used to compile broadscale resolution. (Limited to the sea area under the Eastern IFCAs jurisdiction, however as detailed in the supporting report, this does not affect the score.)
Quality Standards	0	No evidence of any quality standards.
Spawning Indicator	2	No evidence of whether the data used to complete spawning maps come from knowledge of adult fish locations or spawning locations. Assume the latter due to the labelling of the dataset.

2.5.2. Confidence in the ESFJC Data Indicating Spawning Grounds

As the ESFJC datasets are specifically for Atlantic Herring, Sprat and sandeel (where adult sandeel locations are a good indicator of spawning areas), they are very relevant to inform spawning grounds. The ‘importance’ field (target vs. occasional) is unsuitable for confidence as this signifies presence, not confidence in presence. No other parameters are suitable to use, so a uniform confidence approach has been adopted.

2.6. 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).

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

The IHLS data-layers are used to enhance the information used in Stage 1, and inform the combined confidence. IHLS 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. Significant areas of the Humber, Anglian and Outer Thames marine aggregate regions fall outside the IHLS data coverage. Where this is the case, 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 study area and increase the data available for assessment for many of the ‘inner’ Humber region licence and application areas.

The IHLS dataset was supplied in spreadsheet (point) format (stations) for all years 2002-2011, showing a number of fields. Following discussion with Cefas (pers. comm.), 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 this potential issue, 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.

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 3.15 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 3.15 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 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 3.15; 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).

2.6.1. Interpolation of the IHLS Data

2.6.1.1. Preparation of the point data

The IHLS dataset was supplied in point format (stations) for all years 2002 – 2011, showing a number of fields. Following discussion with Cefas (pers. comm.), 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 1) larvae less than 10 mm in the Central North Sea and 2) larvae less than <11 mm in the eastern English Channel/southern North Sea (because of a recognised increased hatching size there) (ECA and RPS, 2011; ICES, 2011).

Each sample or haul repeated the same no./m^2 for every length class and so, firstly, all duplicates were removed. 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 year. As there is a chance this one month did not target 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 this potential issue, any locations where there were 3 samples or fewer, in total, over the period were removed from the dataset. This manipulation 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 manipulated data (i.e. instances of >3 samples) and a good agreement between the two datasets was found.

2.6.1.2. Interpolation

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 (to allow combination with other data layers' confidence assessment), contour lines were created (vector polyline) in a separate file.

The choice of contour intervals was made based on the IHLS point data. By plotting these in four percentile categories, plus zero, the resulting categories shown in the table below were provided by ArcGIS. As equal interval contours were the only available option, 50 unit intervals were applied to the interpolated dataset. Only those contours fitting closely to the percentile categories of the point dataset were kept, with all others deleted. The table below shows the interpolation categories resulting from the contouring.

Table 2.9: International Herring Larvae Survey Abundance/Square Meter Categories

IHLS Point Data Percentile Categories	IHLS Interpolation Categories
0	0
>0 to ≤32	0 - 50
>32 to ≤195	50 - 200
>195 to ≤686	200 - 700
>686 to ≤56258	700 - 56300

The interpolated map was assessed against the original point data and it was found that only the zero category was poorly represented. Therefore this part of the map was created manually through digitisation. Finally, the map was cut to two areas covered by points (eastern English Channel/southern North Sea and central/northern North Sea.

2.6.2. Confidence in the IHLS Data

Number count cannot be used to inform spatial variation in the confidence. To align with other layers' assessment, the confidence should only relate to the standard / credibility of the data, not the scale of spawning. Therefore 0 = absence and ≥1 = present. However these data should not be lost in the assessment process, i.e. number count should still be used to inform the EIA. There were no other fields considered suitable to inform spatial variation of confidence in the data. The table below shows the confidence in the data itself (first five parameters).

Table 2.10: International Herring Larvae Survey Confidence Scores

Confidence test	Score	Rationale
Method	3	IHLS aims at the very young stages of freshly hatched Atlantic Herring in the vicinity of the spawning areas. Sampling is done with a modified Gulf III sampler. Methods have been standardised since 1990. The Multiplicative Larval Abundance Index was used since 1993, compensation mathematically for the gaps in coverage in time and space by utilizing multiple analysis of variance (Patterson and Beverage, 1994). Patterson, K. and Beverage, D.S. (1994) Report of the Herring larvae surveys in the North Sea and adjacent waters in 1994/1995. ICES CM 1994/H:21. Anonymous (1990) Manual for the International Herring Larvae Surveys South of 62°North. ICES, mimeo, 1990.
Vintage	3	A decade of data 2002-2011 has been used to create this layer. This is the most up to date data available at the time of writing and so has a high level of confidence in the distribution and abundance of Atlantic Herring larvae in the central North Sea and eastern English Channel.
Positioning	3	IHLS data contain positional data representing sample locations.
Resolution	3	Each sampling unit is one statistical rectangle of 30 x 30 nm and contains 9 stations, thus providing a representative larvae sampling grid over the entire spawning area. The IHLS dataset has since been interpolated. The interpolation includes all samples that have been surveyed more than or equal to 4 times (whether during one or multiple years). The values interpolated are the maximum value recorded at any one location within the time period. (Only the central North Sea and eastern English Channel regions are covered adequately in relation to aggregate licence areas, however as detailed in the supporting report, this does not affect the score.)
Quality Standards	3	Data collected by separate working groups, with each dataset checked for content and quality by the responsible ICES group.
Spawning Indicator	3	Direct mapping of spawning.

2.6.3. Confidence in the IHLS Data Indicating Spawning Grounds

As 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, as shown in the table above.

3. Combined Confidence Layer

3.1. Confidence in the individual layers

Table 3.1 below shows the results of each of the confidence assessments per layer, plus the final single layer confidence score for Atlantic Herring and sandeel. A key is provided below to show how these were calculated.

Table 3.1: Final Confidence Assessment per individual layer

Confidence test	Method	Vintage	Positioning	Resolution	Quality Standards	Dataset Scoring Source	Total Normalised	Indicator of Herring Spawning	Total Weighted Score	Total Normalised	Indicator of Sandeel Habitat	Total Weighted Score	Total Normalised
Range from 0 to >>	3	3	3	3	3		3	3	30	5			5
Weight	1	1	1	1	1			5			5		
										Herring			**Sandeel**
IHLS	3	3	3	3	3	EMU	3	3	30	**5**			
MAREA Preferred	2	3	3	3	2	MESL	3	1	18	**3**	2	23	**4**
ESFJC	2	2	1	1	0	EMU	1	2	16	**3**	2	16	**3**
Coull et al	1	1	1	2	0	MESL	1	2	15	**3**	2	15	**3**
BGS Preferred	2	1	3	3	2	MESL	2	1	16	**3**	2	21	**4**
VMS	3	3	3	2	3	EMU	3	0	14	**2**	0	14	**2**
MAREA Marginal	2	3	3	3	2	MESL	3	0	13	**2**	0	13	**2**
BGS Marginal	2	1	3	3	2	MESL	2	0	11	**2**	0	11	**2**
IFCA Sightings	2	3	1	1	1	EMU	2	0	8	**1**	0	8	**1**

(light blue box)	= Score provided by consortium
(grey box)	= Value tested in trials
(white box)	= Value not altered in trials
xx	= Final combined confidence score

Key to Table 3.1

Item number	Parameter	Description
1	Method	Provided in confidence proforma (see earlier section). Range 0 to3.
2	Vintage	Provided in confidence proforma (see earlier section). Range 0 to3.
3	Positioning	Provided in confidence proforma (see earlier section). Range 0 to 3.
4	Resolution	Provided in confidence proforma (see earlier section). Range 0 to 3.
5	Quality Standards	Provided in confidence proforma (see earlier section). Range 0 to 3.
6	Dataset Scoring Source	Company delivering scores
7	Total Normalised	Total of above parameter scores (vintage, resolution, quality standards, dataset sourcing source), then normalised back to range 0 to 3. Results rounded to nearest integer.
8	Indicator of Spawning Herring	Provided in confidence proforma (see earlier section). Range 0 to 3.
9	Total Weighted Score Herring	Combined scores, calculated as sum of (vintage, resolution, quality standards, dataset sourcing source) + (5 X indicator of spawning).
10	Total Normalised Herring	Total weighted score normalised back to a range of 0 to 5.
11	Indicator of Spawning Habitat	Provided in confidence proforma (see earlier section). Range 0 to 3.
12	Total Weighted Score Sandeel	Combined scores, calculated as sum of (vintage, resolution, quality standards, dataset sourcing source) + (5 X indicator of spawning).
13	Total Normalised Sandeel	Total weighted score normalised back to a range of 0 to 5.

These 'final single layer' confidence scores represent the value (or weight of evidence) that each dataset has as an 'indicator of Herring spawning/sandeel presence', taking both the quality of the data itself into account as well as it's suitability to be used to indicate locations of Herring spawning/sandeel habitat (i.e. all the previously described 'parameter' scores).

As described previously, each individual layer is first scored on five parameters or tests relating to the data itself: each of these tests result in a score of 0 to 3 (see Section 2). 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 parameter 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 (this does not use the total normalised value detailed above which was provided for reference only). The parameter scores for confidence in the data itself 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 each 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 1.5, were assigned to each shapefile attribute table ready to contribute towards the final combined confidence mapping layers (see Section 3.2).

3.2. Confidence in the combined data-layers

The combined confidence (heat maps) 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. An example is provided in the Table 3.2 below.

Table 3.2: Example of Combined Confidence Score for Herring

Parameter	GIS Attribute Name	Value Score
VMS fishing fleet - pelagic	VMS	2
Coull *et al*. (1998) Herring	Coull	2
ESFJC Herring and Herring sprat	ESFJC	0
IHLS interpolation	IHLS	0
BGS Folk	BGS	3
MAREA Folk	MAREA_REC	0
Combined score using BGS (and excluding MAREA)	TOT_BGS	7
Combined score using MAREA (and excluding BGS)	TOT_MAREA	4
Simplified combined score BGS	CONF_BGS	Medium
Simplified combined score MAREA	CONF_MAREA	Low

The results of the confidence assessment can be seen in the associated GIS files, as well as the IHLS interpolation.

The spreadsheets showing the above information are also made available.

3.2.1. 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 (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 grounds and it is advised that the best seabed sediment data are used at any individual licence, as appropriate. To facilitate the use of either the BGS or the MAREA data, the combined confidence probability have been calculated separately using each of 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.

3.2.2. 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 and BGS preferred/marginal) and for Atlantic Herring, as this would use one extra dataset (IHLS) than available for sandeel. 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' (i).

However, irrespective of what the layer scores actually are, each layer is scored out of 5 and therefore the potential maximum score is 25 (i.e. = 5 (IHLS) + 5 (MAREA preferred) + 5 (ESFJC) + 5 (Coull et al) + 5 (VMS) = 25). This maximum score is termed the 'maximum possible generic score' (ii)

In comparison then, if we had 3 individual layers of medium confidence (3, as with ESFJC, MAREA preferred and Coull et al) and 2 layers not present at any one location, the total score would be 9 out of (i) 16 or (ii) 25. This is reflected in the perceived level of confidence.

Therefore, some factors require consideration when deciding whether to use maximum score for (i) the given data layers or (ii) the potential/generic scores overall. Firstly, what is shown by the total confidence 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. Secondly, it was agreed (MMO, 2013) that these final scores will not be amended if any new data are subsequently available in the future. Instead the scoring provides a 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 or habitat suitable to support sandeel.

Considering the weight of available evidence and the precautionary scoring range, then method (ii) is not relevant e.g. if there was a score of 9 out of 25 using method (ii), this would infer that there is less than moderate confidence, and this isn’t the case, as the greater the number of layers overlapping, the higher the resultant confidence.

Therefore a top range of 16 (the maximum score from layers that could theoretically overlap) was used in the analyses. The actual results only extend up to 12 as the 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.

3.2.3. 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 theoretical total maximum possible score i.e. a score from 13 up to 16 where data layers overlap. However it would be possible to apply this method to the data/results, then insert an additional upper category to extend the range of the ‘heat’ mapping upwards to the maximum possible score resulting from overlaps e.g. extend upwards from maximum achievable score of overlaps (with the existing data e.g. 12 overlaps) to include the score of 13-16. However, it is the view of the EIA WG that this approach lacks a level of scientific credibility.

Therefore intervals of 4 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. Therefore use of categories of multiples of 4 (e.g. as opposed to 5) allows greater differentiation (i.e. 5 would results in only two categories showing data).

Therefore, the score range of 1-16 resulting from layers of data overlap is divided into four categories of ‘heat’ as presented in Table 3.3.

Table 3.3: ‘Heat’ map categorisation

Score of data-layers overlapping	‘Heat’ map category
1-4	**Low**
5-8	**Medium**
9-12	**High**
13-16	**Very high**

There were no results obtained for the ‘very high’ category, though this category is shown on the map legends to account for the maximum possible data layers score.

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

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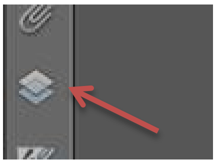
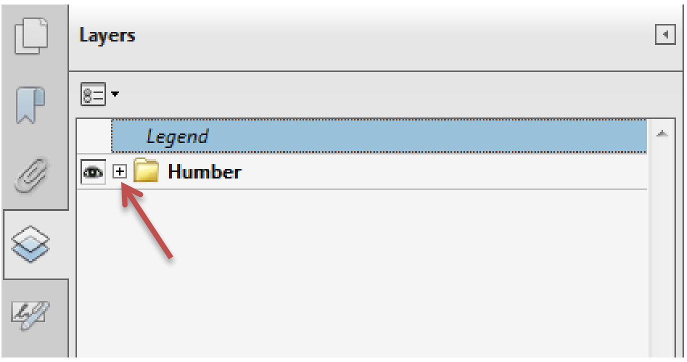
Instructions for using interactive PDF

The spatial datasets used to complete the analysis of herring and sand eel for each region has been presented as an interactive pdf (ipdf). An ipdf provides the user with the ability to switch on and off numerous data-layers, to allow them to observe the methodology used by the EIA working Group. By switching various layers on and off, the user can assess on an individual or cumulative basis the potential for interaction of various receptors, effects and pressures. The ipdf does not allow the user to manipulate the data.

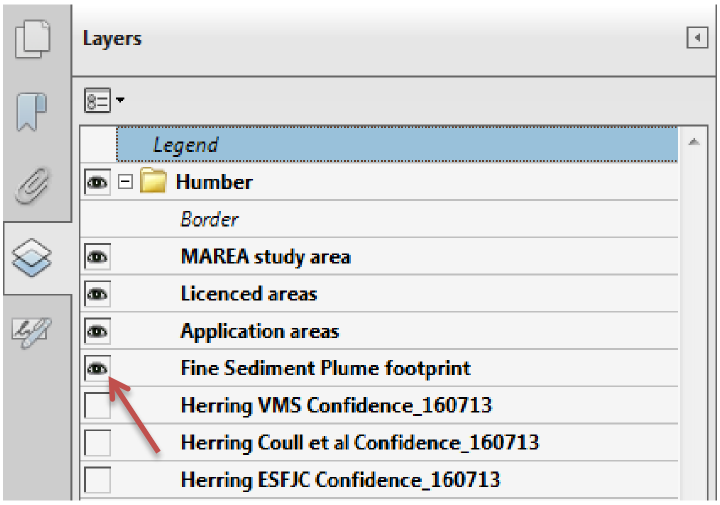
Once the ipdf is opened click on the layer icon on the left-hand menu bar

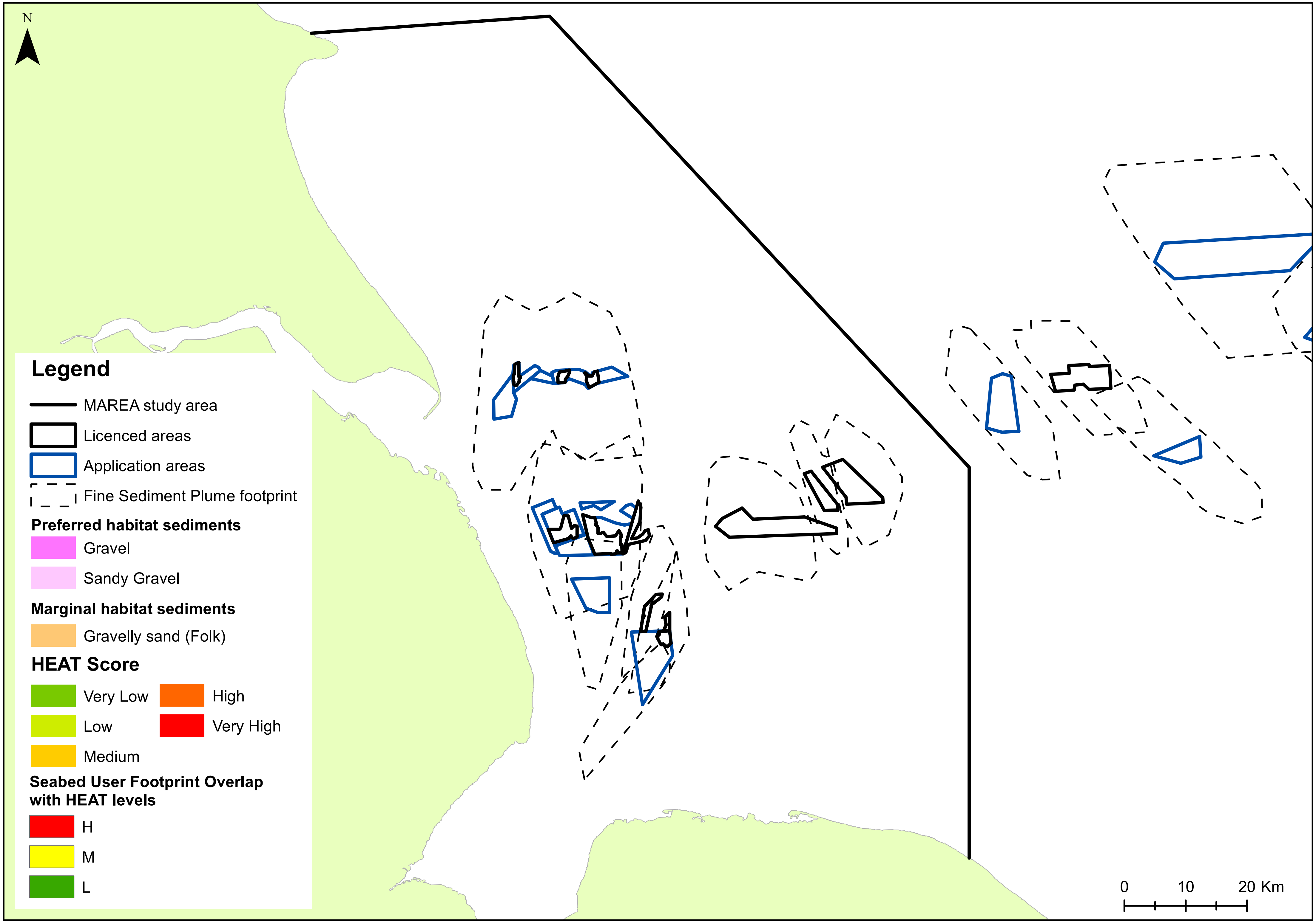


Next click on the + icon between the eye symbol and the region name folder (Humber region shown in example). This expands the folder and shows the data layers.



You can then switch on and off the various data layers by clicking on the appropriate eye icon. If the eye is present the layer is visible, if it is absent the layer is switched off.


Layers
Legend
Humber
Border
MAREA study area
Licenced areas
Application areas
Fine Sediment Plume footprint
Herring VMS Confidence_160713
Herring Coull et al Confidence_160713
Herring ESFJC Confidence_160713


N
Legend
MAREA study area
Licenced areas
Application areas
Fine Sediment Plume footprint
Preferred habitat sediments
Gravel
Sandy Gravel
Marginal habitat sediments
Gravelly sand (Folk)
HEAT Score
Very Low
High
Low
Very High
Medium
Seabed User Footprint Overlap with HEAT levels
H
M
L
0
10
20 Km

Appendix D: Data-layers used for screening Humber 'Outliers' region licence and application areas

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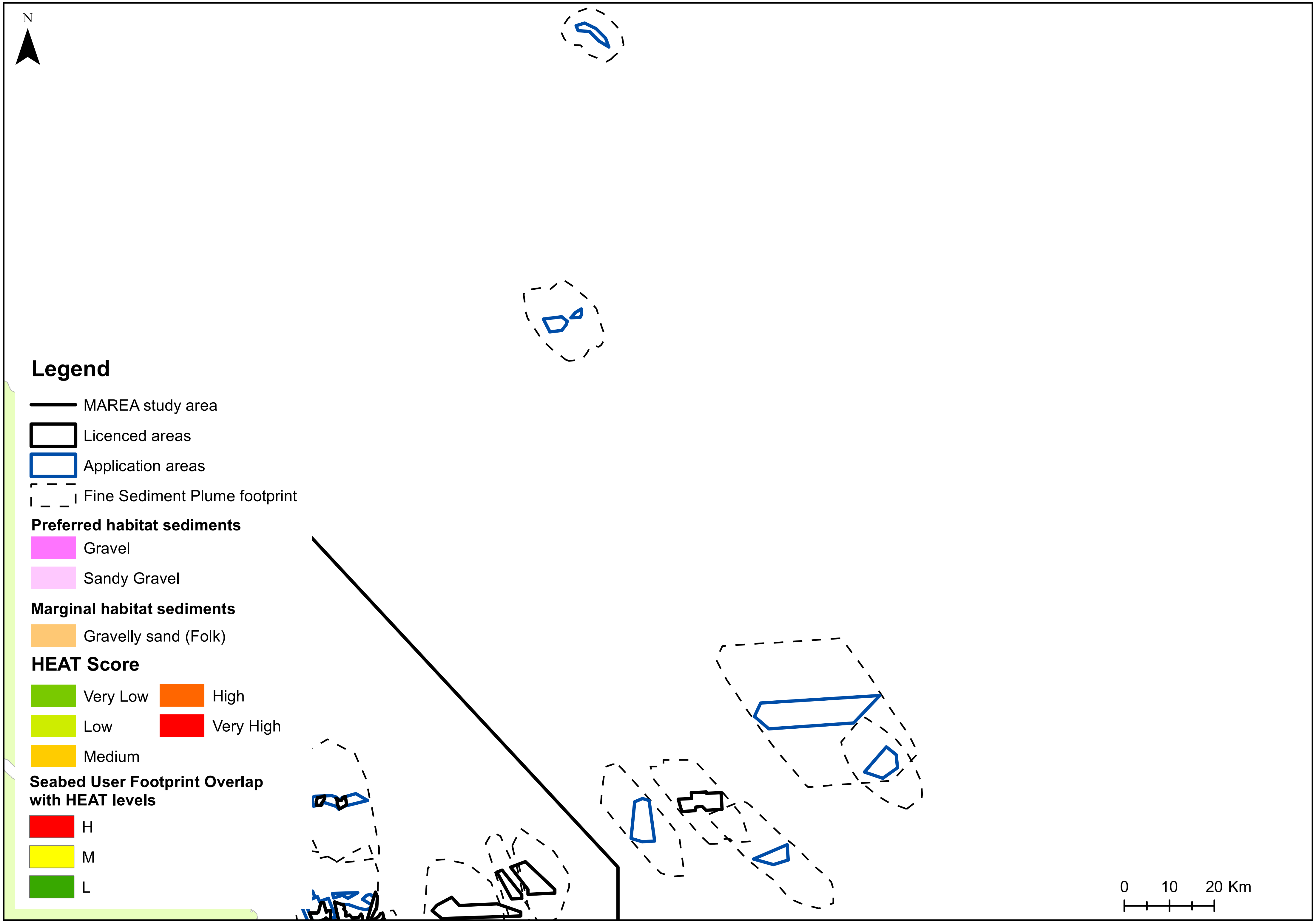
N
Legend
MAREA study area
Licenced areas
Application areas
Fine Sediment Plume footprint
Preferred habitat sediments
Gravel
Sandy Gravel
Marginal habitat sediments
Gravelly sand (Folk)
HEAT Score
Very Low
High
Low
Very High
Medium
Seabed User Footprint Overlap with HEAT levels
H
M
L
0 10 20 Km

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

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N
Legend
MAREA study area
Licenced areas
Application areas
Fine Sediment Plume footprint
Preferred habitat sediments
Gravel
Sandy Gravel
Marginal habitat sediments
Gravelly sand (Folk)
HEAT Score
Very Low
Low
Medium
High
Very High
Seabed User Footprint overlap with HEAT levels
H
M
L
0
8
16 Km

Appendix F: Data-layers used for screening Thames region licence and application areas

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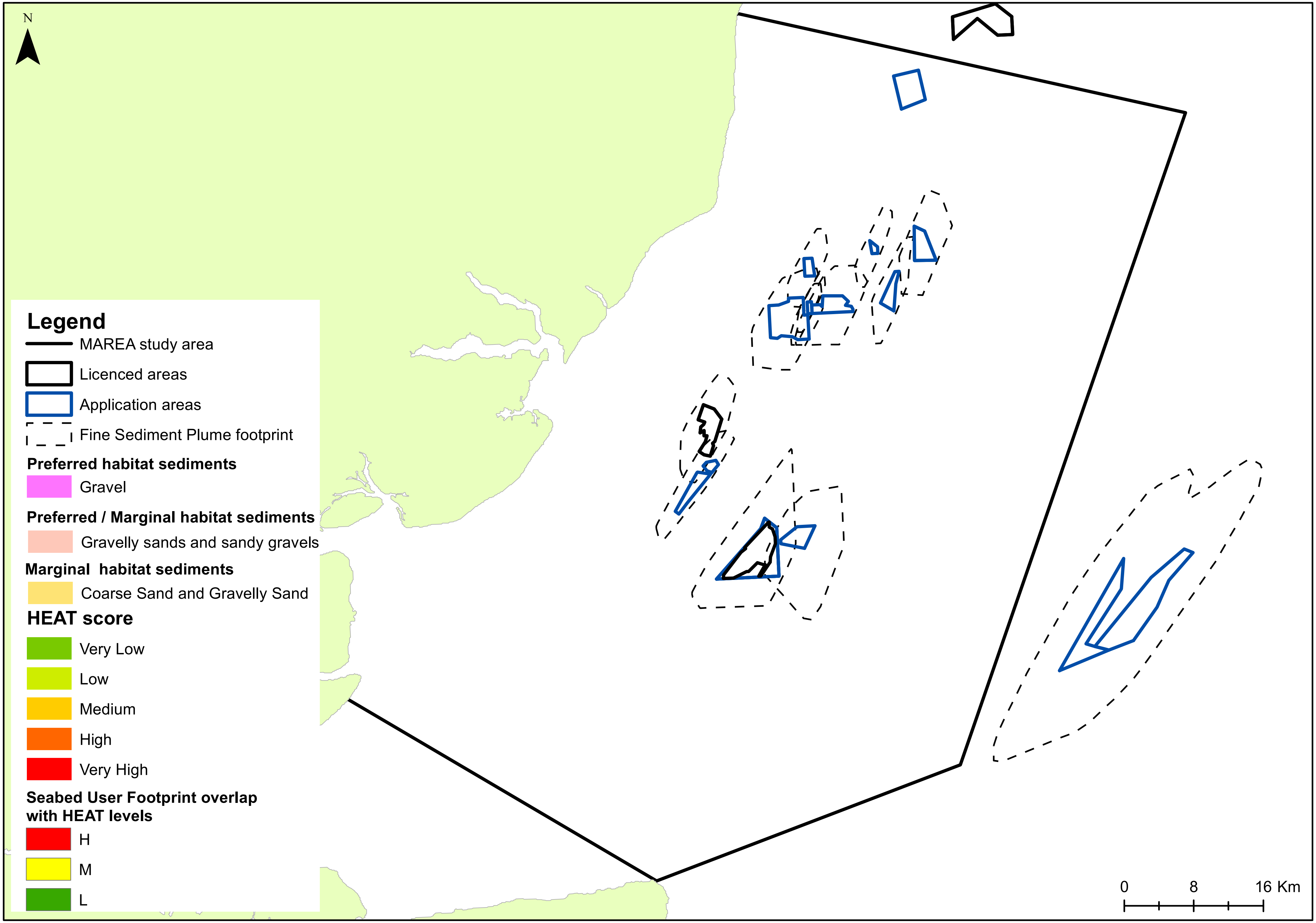
N
Legend
MAREA study area
Licenced areas
Application areas
Fine Sediment Plume footprint
Preferred habitat sediments
Gravel
Preferred / Marginal habitat sediments
Gravelly sands and sandy gravels
Marginal habitat sediments
Coarse Sand and Gravelly Sand
HEAT score
Very Low
Low
Medium
High
Very High
Seabed User Footprint overlap with HEAT levels
H
M
L
0
8
16 Km

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

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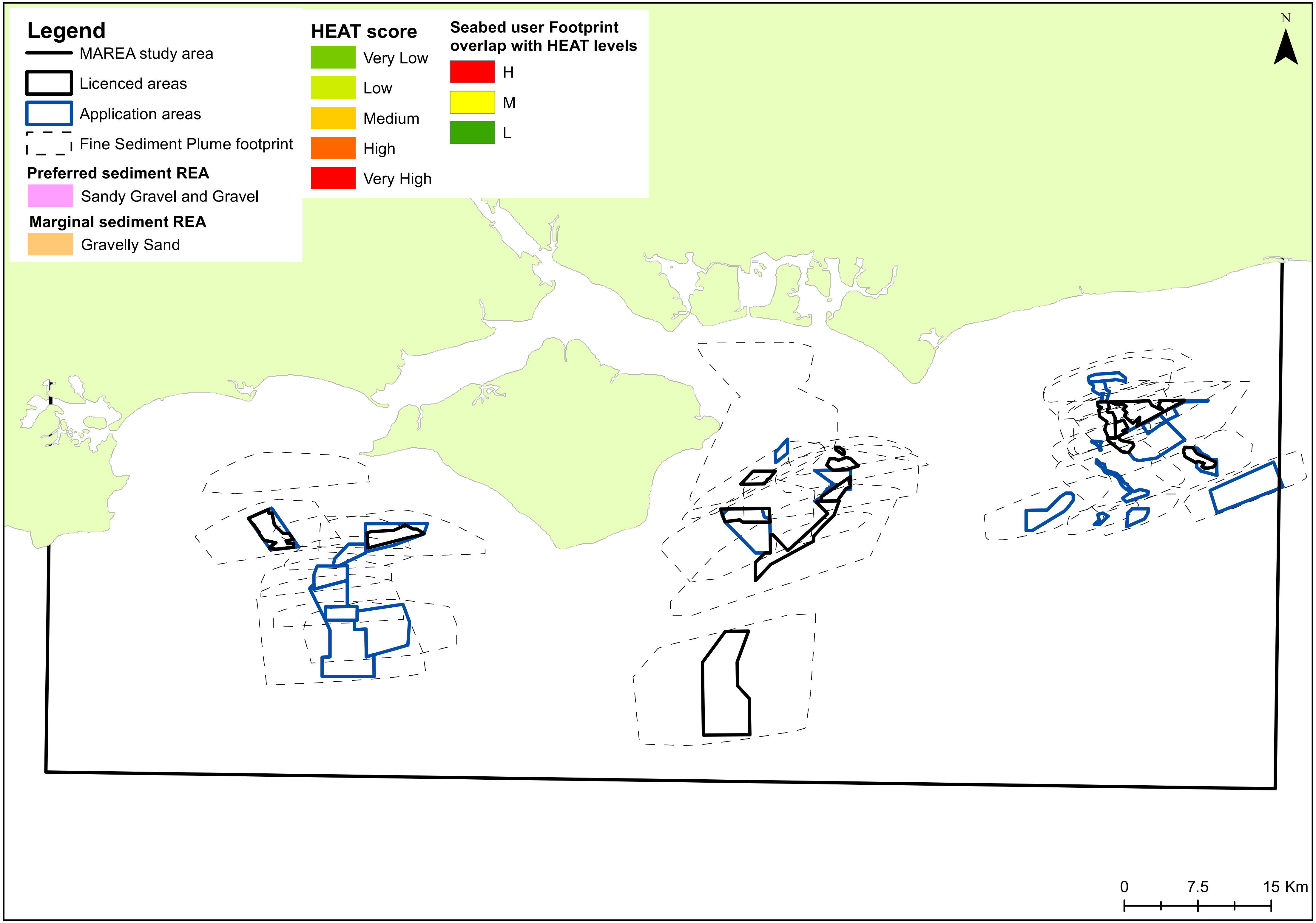

Legend
MAREA study area
Licenced areas
Application areas
Fine Sediment Plume footprint
Preferred sediment REA
Sandy Gravel and Gravel
Marginal sediment REA
Gravelly Sand
HEAT score
Very Low
Low
Medium
High
Very High
Seabed user Footprint overlap with HEAT levels
H
M
L
N
0
7.5
15 Km

Appendix H: Humber Regional Cumulative Impact Assessment

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Assessment of Cumulative Impacts from Marine Aggregate Extraction on Potential Herring Spawning Habitat in the Humber MAREA Region

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1.0. Introduction

Marine Ecological Surveys Limited (MESL) has been commissioned to undertake a cumulative impact assessment (CIA) of the effects of marine aggregate extraction on potential herring spawning habitat in the Humber Region.

This report assesses the cumulative impacts of regional aggregate extraction upon herring spawning habitat in the Humber MAREA region, provides context to marine aggregate extraction activities in the region with reference to other seabed users, and assesses the significance of the results, with regards to receptor sensitivity and magnitude of the potential effects.

This assessment encompasses three main steps:

1. The identification of current marine aggregate extraction areas and application areas in the Humber Region, with reference to potential herring spawning habitat
2. The identification of other seabed users whose activities may interact with potential herring spawning habitat, and the contextualisation of aggregate extraction within the cumulative impact assessment
3. An assessment of the impact significance of aggregate extraction in the Humber Region accounting for other seabed users, and based upon receptor sensitivity and magnitude of effects

The Humber Region is of noted importance for the Banks Atlantic herring (*Clupea harengus*) stock which is known to spawn on discreet habitat types within the area (ICES, 2012). Herring exhibit an affinity for specific sediment habitats during their spawning season; herring are benthic spawners and will only deposit their eggs on coarse sediment classified as either gravel, sandy gravel or gravelly sand (de groot, 1980; Aneer, 1989; Heath *et al.* 1997; Geffen, 2009; Nash *et al.* 2009; ICES 2012). As such, herring are potentially vulnerable to the impacts of aggregate extraction at Areas 400 and 106, which may alter sediment composition of potential spawning habitats or induce secondary impacts (ICES 2012).

Potential areas of herring spawning habitat have been identified within the Humber Region, based on sediment type, the presence of larvae, historic spawning areas and fishing fleet data (see Reach *et al*. 2013 for full methods). The data used in this assessment have been sourced from the EIA Working Group consortium as part of the wider herring and sandeel spawning assessment currently being undertaken to support the aggregates industry in licence renewals.

The Humber MAREA Region currently contains a total of 13 marine aggregate extraction licence areas, and 12 licence application areas. A map of the Humber MAREA current licences and application areas is shown in Figure 1.

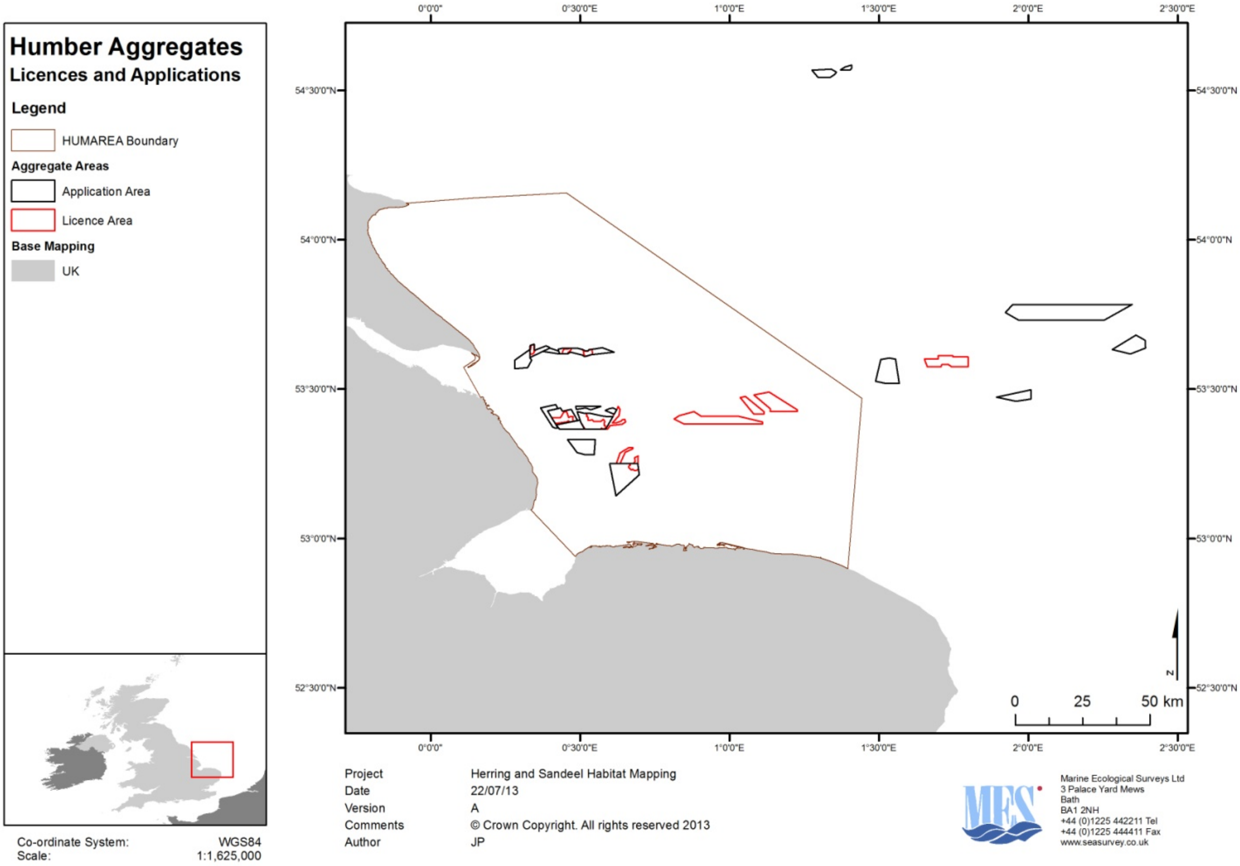

Figure 1. The location of current and application marine aggregate extraction licence areas in the Humber Region and the MAREA boundary.

2.0. Methodology and Data Sources

2.1. Potential Herring Spawning Habitat Data

The data used in the habitat assessment have been sourced from the EIA Working Group consortium as part of the wider herring and sandeel spawning assessment currently being undertaken to support the aggregates industry in licence renewals. Data sourced included:

- Substrate Folk Classification: British Geological Society (BGS)
- Substrate Folk Classification: Marine Aggregate Regional Environmental Assessment (MAREA)
- Fishing Fleet: Vessel Monitoring Systems (VMS) 2007-2011
- Spawning Grounds: Eastern Sea Fisheries Joint Committee (ESFJC)
- Spawning Grounds: Coull *et al* (1998)
- Spawning Grounds: International Herring Larvae Surveys (IHLS) 2002-2011

As detailed in the supporting confidence assessment report (MESL, 2013), each of the data layers were first processed to extract the part of the layer that indicated each of herring spawning habitat (for example, the relevant substrate, gear types).

2.1.1. Confidence Assessment

As data were all required in the same format to inform the combined confidence assessment, any layers not in polygon format were converted, namely the IHLS point dataset. In the first instance, all IHLS data from 2002 -2011 were combined in Excel and then all sample locations that were limited to three or fewer iterations of sampling were removed, in case these did not target the spawning season. A nearest neighbour interpolation was then performed on the dataset, which served to assign abundance values to the areas between sample points. Contours were automatically assigned to the resulting raster dataset, before undergoing conversion to polygons. All analyses were conducted using ArcGIS 9.3.

Each dataset was then assigned a confidence score, based on both confidence in the data itself as well as its reliability as an indicator to herring spawning habitat (each of equal weighting). By combining the different indicator layers together, the individual scores from each layer were combined (ultimately from 1 to 16) for any given location. Scores used throughout this report are classified as follows for ease of presentation:

- Confidence of 1-4 are categorised as 'low' confidence
- Confidence of 5-8 as 'moderate' confidence
- Confidence 9-12 as 'high' confidence
- Confidence 13-16 as 'very high confidence'

See Reach *et al.* (2013) and MESL (2013) for a full account of the confidence processing.

2.2. Impact Assessment

The cumulative assessment methods utilised in this report follow those presented in the Marine Aggregate Regional Environmental Assessment of the Humber and Outer Wash Region (Humber MAREA) (ERM 2012). The methods have been slightly adjusted where appropriate to suit the current assessment objectives, and to reflect the fact that only one receptor is being assessed in the case of herring spawning habitats.

Effect-Receptor pathways have been identified by the EIA WG and agreed with the MMO and RAG for the impacts of aggregate extraction on herring spawning habitat. Over the following sections, each impact pathway is assessed in terms of magnitude, which is combined with the receptor value and sensitivity to produce a significance classification. These individual significance classifications are then combined, which, along with consideration of the cumulative impacts from other industries, gives the regional significance of marine aggregate extraction on potential herring spawning habitat in the Humber Region.

2.2.1. Predicting Effect Magnitude

In accordance with the Humber MAREA, the potential magnitude of each effect is assessed with reference to four variables: extent, duration, frequency and elevation above baseline conditions. A combination of assessments against these variables determines the magnitude of the effect. The components of magnitude are indicated in Figure 2. A detailed description and the definition of each magnitude factor is discussed in ERM (2012).

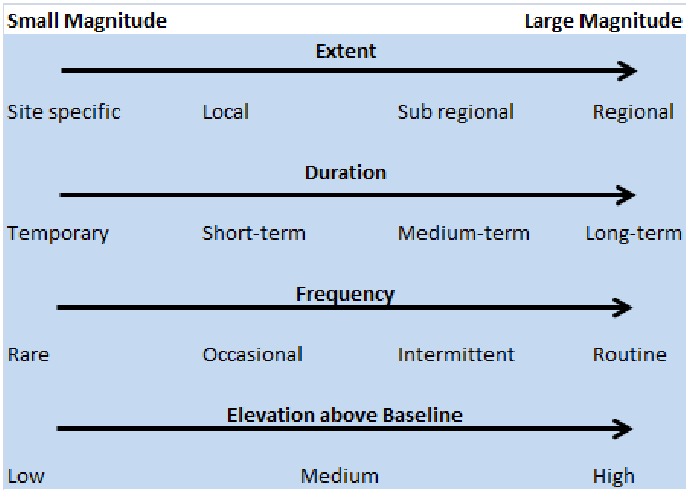

Figure 2. The components of magnitude used in this assessment (adapted from ERM, 2012).

Magnitude has been assigned using expert opinion and information regarding the likely impacts arising from aggregate extraction (e.g. ERM, 20112). As such, the assessment process is subjective, although a reasonable degree of consensus has been sought when classifying exposure pathways.

2.2.2. Determining Receptor Value and Sensitivity

The determination of receptor value and sensitivity adopts a similar approach as to that for magnitude of potential effects, taking receptor tolerance, adaptability and recoverability into account. The categories used for defining sensitivity are shown in Figure 3. Much of the information needed to inform this assessment has been collated as part of the herring spawning habitat assessment methodology (Reach *et al*. 2013), or from the Humber MAREA (ERM, 2012).

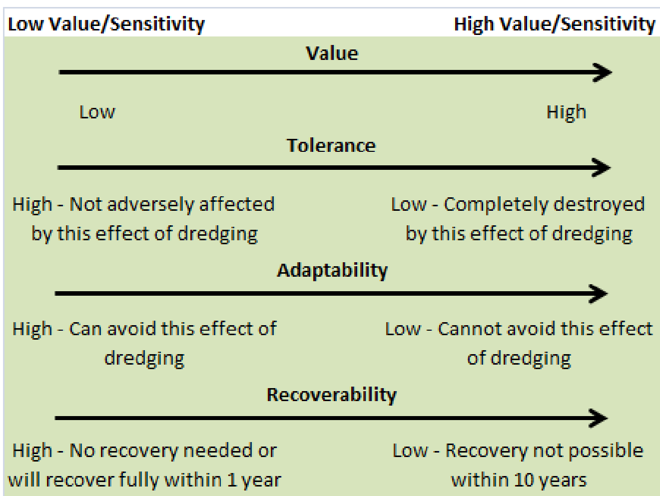

Figure 3. The components of sensitivity used in this assessment (adapted from ERM, 2012).

2.2.3. Determining Impact Significance

Following the assessment of the magnitude of potential effects and the receptor sensitivity and value for each impact pathway, overall impact significance is be assigned according to the classifications presented in Figure 4 and in Table 1. A level of the degree of interaction between the magnitude of effects and the receptors is also taken into account in assigning impact significance.

The assessment of impact significance is a subjective process, although is based on expert opinion and general consensus of the likelihood of the receptor suffering impact from the expected effects.

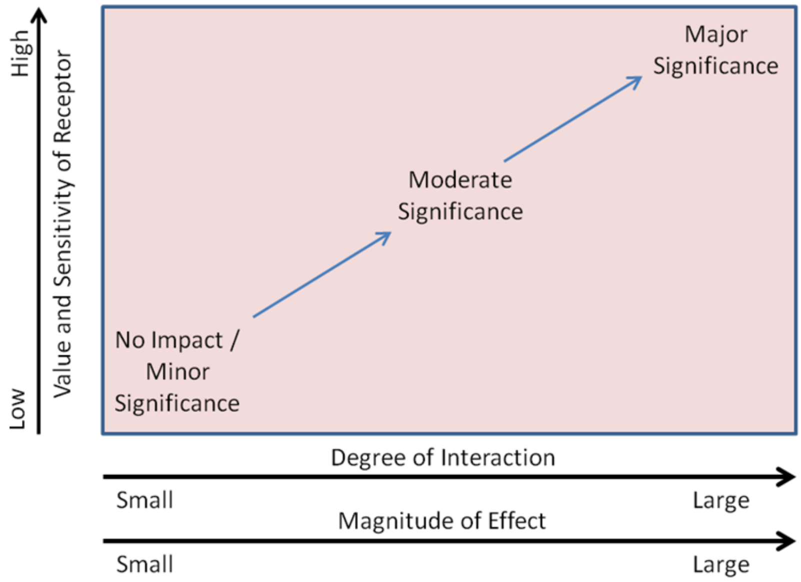

Figure 4. Scales used to define impact significance in this study (adapted from ERM, 2012).

Table 1. Definitions of Impact Significance (ERM, 2012).

Impact Significance	
Not Significant	Impacts that, after assessment, were found to be not significant in the context of the MAREA objectives
Minor Significance	Impacts that warrant the attention of particular stakeholders but no action is required if the impacts can be controlled by adopting normal good working practice
Moderate Significance	Regional impacts that should be recognised and addressed in consultation with particular stakeholders
Major Significance	Regional impacts that are not environmentally sustainable and compromise the continuation of extraction activity in the region

3.0. Cumulative Impact Assessment of Potential Impacts on Herring Spawning Habitat

3.1. Identification of Interactions between Marine Aggregate Extraction Areas/Application Areas and Potential Herring Spawning Habitat in the Humber MAREA Region

Current marine aggregate extraction areas and application areas in the Humber MAREA Region are shown with reference to potential herring spawning areas in Figure 5 (derived using the methods presented in Reach *et al*. 2013 and the associated confidence assessment (MESL 2013). These have been plotted in conjunction with the 'worst-case scenario' secondary impact zones provided to the EIA WG.

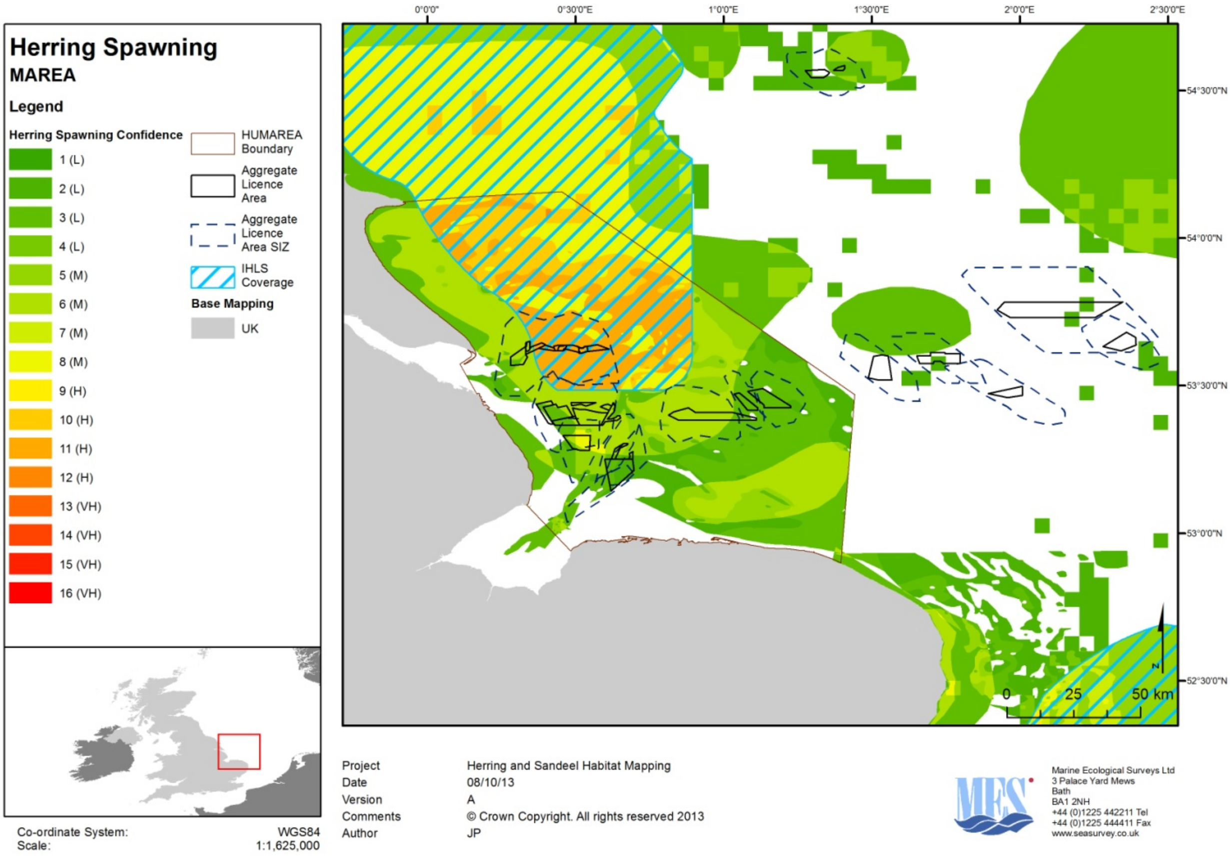

Figure 5. Current and application marine aggregate extraction areas in the Humber Region and their associated secondary impact zones overlain onto potential herring spawning areas (split by confidence) (Reach *et al*. (2013). The IHLS herring larvae data layer is also shown.

Herring larvae data from the ICES International Herring Larvae Surveys (IHLS) are also presented in Figure 5. Whilst these data are included within the overall confidence assessment, the layer has been shown individually, due to it being the only direct measure of spawning (see confidence assessment, MESL 2013). However it has not been made to automatically force the combined confidence assessment to high as the layer has been interpolated from point data. Whilst the IHLS dataset conforms to repeated grid sampling at fixed locations, these are far apart (e.g. ~20km). Note that the data layer is not based on any relative abundance scores, as low abundances can be equally as significant as high levels (Cefas, pers. comms); therefore it shows only presence/absence of 0-ringer yolk-sac herring larvae which indicate spawning. It should be noted that there are limitations associated with IHLS data in informing herring spawning locations, such as the limited survey coverage and gear restrictions which may exclude some herring larvae close to the seabed.

Using the data layers shown in Figure 5, the percentage of the overlap between current, application and option aggregate extraction sites and potential herring spawning habitat have been calculated, as shown in Table 2. The data have been split by primary impact zone (PIZ) and combined primary and secondary impact zones (PIZ + SIZ) for current and application areas.

Table 2. The regional footprint of marine aggregate extraction areas (current, application and options) overlapping herring spawning habitat in the Humber MAREA Region (as identified in Figure 5).

	Very high confidence habitat overlap as % of entire area	High confidence habitat overlap as % of entire area	Moderate confidence habitat overlap as % of entire area	Low confidence habitat overlap as % of entire area	Total percentage of potential spawning area overlapped by marine aggregate extraction
Current Licences (PIZ)	0.00	0.08	1.01	0.92	2.00
Current Licences (PIZ + SIZ)	0.00	0.75	7.79	5.43	13.96
Applications (PIZ)	0.00	0.37	1.16	1.17	2.70
Applications (PIZ + SIZ)	0.00	5.66	6.19	3.32	15.17
Options	0.00	0.00	0.49	0.23	0.72

Table 2 indicates the regional footprint of aggregate activity in the Humber Region, and identifies the interaction overlap between dredging and potential herring spawning areas. It can be seen that current aggregate extraction areas in the Humber Region overlap with 2% of the total available spawning habitat. When the secondary impact zone from these areas is included, this figure extends to 13.96%, although it should be noted that in both cases, the majority of habitat overlapped is low and moderate confidence. Similar percentage overlaps are apparent when application areas are considered (2.70% of total habitat overlapped by PIZ, 15.17% of total habitat overlapped by PIZ and SIZ). Aggregate option areas cover a minor percentage of moderate and low confidence habitats. No very high confidence habitats are overlapped by any current or proposed aggregate extraction areas.

Only Area 514 (split into Areas 514/2, 514/3 and 514/4) overlaps with the IHLS interpolated spawning data in the Humber Region, comprising of 0.03% of the total IHLS footprint (regardless of MAREA boundaries).

3.2. Identification of Interactions between other Seabed Users and Herring Potential Spawning Areas in the Humber MAREA Region

Following on from the assessment of the regional aggregate extraction footprint, this section identifies the interactions between other seabed users and potential herring spawning areas. The following benthic impacting sectors are considered in the assessment:

- Offshore Windfarms (current and proposed)
- Potential offshore windfarms corridors
- Cable and pipeline routes
- Disposal sites
- Commercial fishing (trawl and dredge)

It should be noted that cable and pipeline routes include both current and predicted export cable route pathways for proposed windfarm developments which are assessed to be the worst case scenario footprint for future years, i.e. the route which encompasses the greatest amount of herring spawning habitat. Cable routes have been buffered by 300mm to produce polygons in GIS.

A map of the cumulative footprint all seabed users is presented with respect to potential herring spawning areas in Figure 6.

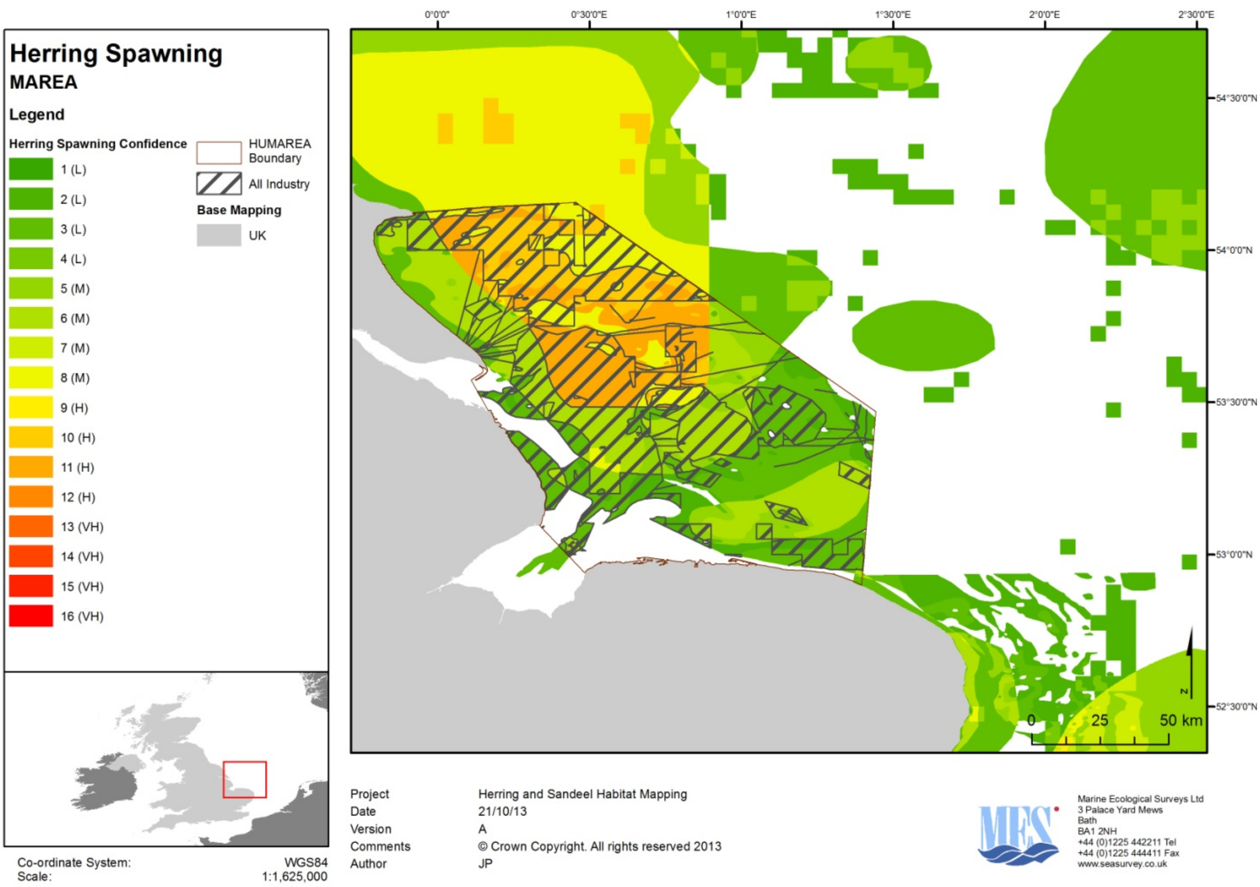

Figure 6. Thematic map of the footprint of all seabed users considered in this assessment in the Humber Region overlain onto potential herring spawning areas (split by confidence). Data are taken from the GIS layers

compiled by the EIA WG during Phase 1 of the herring spawning habitat assessment, following the methods outlined in Reach *et al*. (2013) and the subsequent confidence assessment (MESL, 2013).

Percentage overlaps of each impact sector on potential herring spawning habitat have been calculated, as for the aggregate extraction areas, presented in Table 3. The figures inform the regional footprint of each benthic impacting seabed user against which the footprint of regional aggregate extraction can be contextualised.

Table 3. The regional footprint of all seabed users considered in this assessment overlapping potential herring spawning areas in the Humber Region (as identified in Figure 6).

	Very high confidence overlap as % of entire area	High confidence overlap as % of entire area	Moderate confidence overlap as % of entire area	Low confidence overlap as % of entire area	Total percentage overlap regardless of confidence
Aggregate Options	0.00	0.00	0.49	0.23	0.72
Application Licence Areas	0.00	0.37	1.16	1.17	2.70
Current Licence Area	0.00	0.08	1.01	0.92	2.00
Application Licence Area Including SIZ	0.00	5.66	6.19	3.32	15.17
Current Licence Areas inc SIZ	0.00	0.75	7.79	5.43	13.96
Demersal Trawling Footprint	0.00	9.58	7.45	8.36	25.39
Disposal Sites	0.00	0.64	0.43	0.48	1.54
Fisheries Dredging Footprint	0.00	6.90	2.67	0.33	9.90
Operating Windfarm Turbine footprint	0.00	0.00	0.00	0.00	0.00
Pipelines	0.00	0.00	0.00	0.00	0.01
Power Cables	0.00	0.00	0.00	0.00	0.00
Proposed Windfarm Sites - Indicative Turbine Footprint	0.00	0.01	0.02	0.00	0.03
Telecommunications Cables	0.00	0.00	0.00	0.00	0.00
Windfarm Licence Areas Proposed	0.00	3.51	6.58	0.83	10.92
Windfarm Licence Areas under Construction	0.00	0.00	0.05	0.29	0.34
Worst-Case Proposed Power Cables	0.00	0.00	0.00	0.00	0.00
Total Industry Overlap Regardless of Confidence					**54.19**

It can be seen from Table 3 that the total combined footprint of all benthic impacting seabed sectors is 54.19% of the total herring spawning habitat available in the Humber MAREA area. The majority of overlap occurs within moderate confidence herring spawning areas, although this is closely followed by high confidence herring spawning habitats.

Excluding aggregate extraction, commercial trawling, proposed windfarm sites, and commercial dredge trawling contribute the greatest to total regional herring spawning habitat overlaps (25.39%, 10.92% and 9.90% of the total habitat available respectively). The majority of the combined industry overlap (excluding aggregates) occurs in high confidence spawning areas.

In terms of contextualising the contribution of marine aggregate extraction to regional cumulative impacts from all sectors, it can be seen that current aggregate extraction areas (PIZ) overlap with 2.0% of the total spawning habitat available and aggregate application areas overlap with 2.7% of total habitat available, compared to much larger overlap from other impact sectors. When the secondary impact zones are considered, these overlaps increase, although are below the level of overlap observed for commercial fishing, and other combined sectors. The majority of overlap for both current and application areas occurs with moderate or low confidence habitat.

3.3. Assessing significance of Impact upon Potential Herring Spawning Habitat in the Humber MAREA Region from Aggregate Extraction

This section utilises the methodology presented in Section 2.0. to assign significance to the regional impacts of aggregate extraction on herring spawning habitat in the Humber Region.

For the purposes of this assessment, the potential effect-receptor pathways of aggregate dredging (or other sectors) on spawning activity were agreed with the MMO and RAG during the project conception stage (at a meeting held on 01 May 2013 (MMO, 2013). These were agreed to be as follows:

- Impacts in the Primary Impact Zone (PIZ)with the Potential to affect Herring Spawning Habitat
  - Direct removal of suitable sediment
  - Direct removal of eggs
  - Alteration of habitat structure
  - Recovery of suitable habitat to support future possible spawning activity (*re-colonisation*)
- Impacts in the Secondary Impact Zone (SIZ) with the Potential to affect Herring Spawning Habitat
  - Smothering of eggs
  - Fining of suitable habitat
  - Recovery of suitable habitat to support future possible spawning activity (*re-colonisation*)

It has been agreed that potential effects of sediment plumes on herring larvae, the entrainment of larvae and adults and any effects relating to adult populations outside those listed above are not to be considered in the context of this report (MMO, 2013).

3.3.1. Magnitude of Impacts

The magnitude of each marine aggregate extraction effect-receptor pathway identified for this assessment is considered below with regard to potential herring spawning habitat:

Direct removal of suitable sediment (PIZ):

The direct removal of suitable sediment is likely to affect regional herring spawning at the **site-specific** scale and over a **short-term** duration, although sediment will only be removed during active dredging, within the ADZ of the licence areas. This effect will occur on an **intermittent** basis, as sediment will be removed with each dredge event, although interactions may be limited. Elevation above baseline is however expected to be **low**, given the low overlaps between aggregate area ADZs and the total herring spawning habitat in the region (2% for current areas, 2.7% for application areas). Further to this, it is unlikely that suitable sediment will be completely removed during the dredging process. It is therefore considered that the overall magnitude of direct removal of sediment within the PIZ on herring spawning is **low**.

Direct removal of eggs (PIZ):

The extent of direct removal of eggs from regional aggregate extraction activities in the Humber Region is assessed to be **site specific**, with egg removal only occurring in the ADZ of the PIZs of each licence area. The duration of effects is assessed to be **short-term**, reflecting the active removal of eggs during dredging operations, and the annual frequency of herring spawning. The effect is likely to occur on an **occasional** basis. Although dredging has the potential to cause this effect on a routine basis, the confidence in herring spawning areas indicates that eggs are not likely to be present at all sites, rendering frequency of the effect lower than apparent. The elevation above baseline is assessed to be **low-moderate** given the wide range of potential habitat in the region. The overall magnitude of direct removal of eggs within the PIZ on herring spawning is considered to be **low**.

Alteration of habitat structure (PIZ):

Alteration of habitat structure within the regional PIZ footprint is likely to be **site-specific** and **medium-term**, the effects only occurring in the active dredging areas of each PIZ, with the effects lasting for not more than 10 years, during which time seabed recovery is expected (Hill *et al*. 2011). The frequency of this effect is anticipated to be **occasional**. Whilst dredging has the potential to alter seabed habitats, this is dependent on differing seabed sub-strata being left in place following dredging, and it is unlikely that substantial changes in seabed sediment will occur at the regional scale. Elevation above baseline is anticipated to be **low**, and overall magnitude of effects arising from the alteration of habitat structure within the PIZ is considered to be **low-medium**.

Recovery of suitable habitat (PIZ):

The magnitude of the effects of aggregate extraction on the potential for spawning habitat recovery is assessed to be **site-specific** and generally **short-term**, given the small areas involved (2% total for current areas, 2.7% total for application areas, 0.08% high confidence spawning habitat for current areas, 0.37% high confidence spawning habitat for application areas). Recovery of the seabed from the effects of aggregate dredging in the Humber is thought to be relatively short term (Hill *et al*. 2011). Only **occasional** effects are thought to be likely which impact a sites ability to recover, and a **low** elevation above the baseline recovery is anticipated. It is therefore considered that the overall magnitude of effects of dredging at the regional scale on the ability of herring spawning habitat to recover is **low**.

Smothering of eggs (SIZ):

The smoothing of eggs in the secondary impact zone is assessed to be **localised**, given the secondary plumes extend out of the licence areas in the regional consideration (~11.96% of the total regional herring spawning area for current areas, ~12.47% for application areas). The duration of effects is expected to be **short-term**, given the frequency of aggregate extraction, the limited herring spawning season, and the annual frequency of spawning events. The frequency of the effect is likely to be **occasional**, allowing for the low level of likely interaction between the actual presence of eggs, and smothering of a significant enough level to cause an effect. The elevation above baseline is expected to be **low** for the same reasons. Overall magnitude of effects from smothering of eggs in the SIZ is assessed to be **low** at the regional scale.

Fining of suitable habitat (SIZ):

The fining of suitable habitat resulting from aggregate extraction has the potential to cause **localised** effects on herring spawning within the regional SIZ footprint. The duration of fining effects is expected to be **short-term**, and the frequency **occasional**, given the likelihood of sediments outside the PIZ being suitable for herring spawning, and changes of a high enough order of magnitude to deter herring spawning occurring. Elevation above baseline is therefore expected to **low**, especially considering the proportion of low confidence herring spawning areas contributing to the overlap. It is therefore considered that the overall magnitude of fining of suitable habitat in the SIZ on herring spawning is **low**.

Recovery of suitable habitat (SIZ):

The extent of the effects of aggregate extraction on the potential for spawning habitat recovery is assessed to be **local** and generally **short-term**, given the relatively small areas involved (~11.96% of the total regional herring spawning area for current areas, ~12.47% for application areas).Recovery of the seabed from the secondary effects of aggregate dredging in the Humber Region is thought to be relatively short term (Hill *et al*. 2011). Only **occasional** effects are thought to be likely which impact a sites ability to recover, and a **low** elevation above the baseline recovery is anticipated. It is therefore considered that the overall magnitude of effects of dredging at the regional scale on the ability of herring spawning habitat to recover in the SIZ is **low**.

3.3.2. Sensitivity of Receptor

A sensitivity assessment of regional herring spawning in the Humber Region to the identified effect-receptor pathways is presented below.

Part of the receptor sensitivity is the definition of the receptor value. As a receptor, herring spawning habitat is considered to be **medium** in value. This reflects the importance of herring as a species (UKBAP listed), the importance of the Humber Region to the Banks herring stock as a spawning ground, and the economic value of the spawning grounds. The receptor is however decreased in value due to the scale of potential habitat in the region, and the split between areas of high, medium and low spawning confidence. Table 1 illustrates that the majority of regional extraction areas overlap with low confidence spawning areas, rendering receptor value lower at these sites. It is considered that the overall magnitude of effects of dredging at the regional scale on the ability of herring spawning habitat sites to recover is low.

Direct removal of suitable sediment (PIZ):

Herring spawning habitat has a low tolerance and adaptability to the direct removal of sediment in areas where the spawning occurs. However, considering the exposure of regional aggregate licence areas to suitable habitat (high confidence spawning areas), this assessment considers that the overall tolerance is **medium**, as the distribution of suitable habitat at the regional level is limited. Herring spawning has a **medium** adaptability to aggregate extraction, as herring will not spawn in areas of unsuitable sediment (e.g. de Groot, 1979; Blaxter, 1980; Skaret *et al*. 2003; Greenstreet *et al*. 2010), although once eggs are deposited they are vulnerable to the effects of aggregate extraction, and cannot adapt. Relative exposure however plays a factor, and thus adaptability is classified as medium. Recoverability of the receptor is assessed to be **high** given the regional spawning habitat available, and the annual frequency of spawning event. Overall sensitivity of the receptor to the direct removal of sediment in the PIZ is considered **medium**.

Direct removal of eggs (PIZ):

Herring spawning habitat generally has a low tolerance and adaptability to the direct removal of eggs, as physical removal is likely to have an immediate impact upon recruitment. However, given the scale of potential herring spawning in the Humber Region, receptor sensitivity is lowered based on the limited interactions likely to occur. This assessment therefore assigns a **medium-low** tolerance of herring spawning to the direct removal of eggs. Adaptability is assessed to be **low**, although recoverability is **high** (depending on cumulative factors) as no recovery of lost eggs is likely to be possible until the next spawning event. It is therefore considered that the overall sensitivity of herring spawning habitat to the direct removal of eggs is **high** at the regional scale.

Alteration of habitat structure (PIZ):

Herring spawning habitat is likely to have a **low** tolerance to the alteration of habitat structure, given the affinity to specific sediment types favoured for spawning (e.g. de Groot, 1979; Blaxter, 1980; Skaret *et al*. 2003; Greenstreet *et al*. 2010). Herring are however known to favour a range of sediment types within certain thresholds (e.g. Bowers, 1980; Maravellias *et al*, 2000; Nash *et al*. 2009). Adaptability to changes in habitat structure is therefore classified as **medium**. Recoverability is assessed to be **medium**, based on the fact that dredge operators are required to leave the seabed in a similar state to which it was found following the cessation of dredging. Overall sensitivity of herring spawning habitats to the alteration of habitat structure is considered **medium**.

Recovery of suitable habitat (PIZ):

Herring spawning habitat is considered to have **Medium-high** tolerance to impacts affecting recoverability in the PIZ, **medium** adaptability and **medium** recoverability overall, given the regional footprint in the PIZ and the environmental characteristics of the region (Hill *et al*. 2011). Overall sensitivity of herring spawning habitats to impacts affecting the potential for recovery is considered **medium**.

Smothering of eggs (SIZ):

Herring spawning habitat is likely to have a low tolerance and adaptability to smothering of eggs given that eggs are spawned directly onto sediment (de Groot 1979), and any significant smothering is likely to result in reduced recruitment. However the regional SIZ from aggregate extraction is limited in size (especially where overlapping high spawning confidence areas), thus overall tolerance is considered **medium**. Adaptability to smothering is considered **low-medium**, given the immobile nature of eggs, and the inability of spawning to avoid impacts. Immediate recoverability is likely to be low given the vulnerable nature of the benthic eggs, however for this assessment the recoverability is assessed as **medium** given the range of available spawning habitat in the region and the annual frequency of spawning. It is therefore considered that the overall sensitivity of herring spawning habitat to the smothering removal of eggs in the SIZ is **medium** at the regional scale.

Fining of suitable habitat (SIZ):

Herring spawning habitat is likely to have a low tolerance to the fining of suitable habitat outside of aggregate extraction areas, given the affinity to specific sediment types favoured for spawning (e.g. de Groot, 1979; Blaxter, 1980; Skaret *et al*. 2003; Greenstreet *et al*. 2010). However, given the scale at which these effects are likely to occur, the total spawning habitat available in the region, and the confidence of the overlaps observed, tolerance for this assessment is considered to be **medium**. Adaptability to the fining of sediments is low in specific areas, although as suitable habitats are widespread on a regional basis, adaptability is considered to be **high**. Recoverability is assessed to be **high** for the same reasons, thus overall sensitivity of herring spawning to the fining of habitats is considered **medium**. Overall sensitivity of herring spawning habitats to impacts affecting the potential for recovery is considered **medium**.

Recovery of suitable habitat (SIZ):

Herring spawning habitat is assessed to have a **high** tolerance to the impacts likely to affect recoverability in the PIZ, **high** adaptability and **medium** recoverability overall, given the likely effects in the SIZ, the regional footprint in the PIZ and the environmental characteristics of the region (Hill *et al*. 2011).

3.3.3. Evaluating Impact Significance

Following assessment of the potential effects of regional aggregate extraction on herring spawning habitat according to the magnitude of, and sensitivity to the individual impact pathways, the overall significance of the effects can be determined.

Based on the information presented in the above sections, an overall significance level has been assigned to each effect-receptor pathway in accordance with the determination scale presented in Figure 4. The overall significance of each effect pathway is shown in Table 4.

Table 4. Summary of impact significance of regional aggregate extraction in the Humber Region on potential herring spawning habitat

Impact Pathway	Significance	Rationale
Direct removal of suitable sediment	**Minor Significance**	Based on the general low magnitude of effects, the medium receptor value, the medium receptor sensitivity, and the low levels of likely exposure given the wider habitat available, the cumulative impact of direct sediment removal on potential herring spawning habitat is considered to be of minor significance in the regional context.
Direct removal of eggs	**Moderate Significance**	Based on the low-moderate magnitude of potential effects, the medium receptor value, the medium-high receptor sensitivity, and the likely degree of interaction between the effect and the receptor, the cumulative impact of direct egg removal on potential herring spawning is considered to be of moderate significance at the regional level.
Alteration of habitat structure	**Minor Significance**	Based on the low-medium magnitude of effects, the medium receptor value, the general medium receptor sensitivity, and the levels of likely exposure given the wider habitat available, the cumulative impact of the alteration of habitat structure on potential herring spawning habitat is considered to be of minor significance in the regional context.
Recovery of suitable habitat (PIZ)	**Minor Significance**	Based on the general low magnitude of potential effects, the medium receptor value and the medium receptor sensitivity, the cumulative impact of aggregate extraction on the ability of the potential spawning habitat to recover is assessed to be of minor significance at the regional scale.
Smothering of eggs	**Minor Significance**	Based on the low-medium magnitude of potential effects, the medium value and general moderate sensitivity of the receptor, and the low-medium degree of interaction between the receptor and the effect, the cumulative impact significance of smothering of eggs on herring spawning is considered to be minor at the regional level.
Fining of suitable habitat	**Minor Significance**	Based on the low-medium magnitude of potential effects, the medium value and low-moderate sensitivity of the receptor, and the low-medium degree of interaction between the receptor and the effect in the SIZ, the cumulative impact of habitat fining on herring spawning habitat is considered to be minor at the regional level.
Recovery of suitable habitat (SIZ)	**Minor Significance**	Based on the general low magnitude of potential effects, the medium receptor value and the low-medium receptor sensitivity, the cumulative impact of aggregate extraction on the ability of potential spawning habitat to recover is assessed to be of minor

		significance at the regional scale.

Based on the above assessments and the information presented in Tables 2 and 3, it can therefore be said that the cumulative impact of marine aggregate extraction on herring spawning in the Humber Region is of minor significance at the regional scale.

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Appendix I: Anglian Regional Cumulative Impact Assessment

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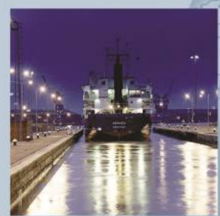
British Marine Aggregate Producers Association

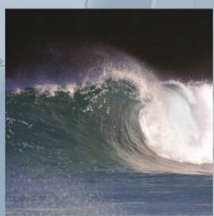
Assessment of Cumulative Impacts on Spawning Herring from Marine Aggregates Extraction in the Anglian Region

Report R.2165

November 2013

Creating sustainable solutions for the marine environment





British Marine Aggregate Producers Association

Assessment of Cumulative Impacts on Spawning Herring from Marine Aggregates Extraction in the Anglian Region

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Summary

As part of the Marine Aggregate Environmental Impact Assessment (EIA) Working Group, ABP Marine Environmental Research Ltd (ABPmer) was commissioned to undertake a cumulative assessment of the effects of marine aggregates dredging and other projects and activities on spawning Atlantic herring (*Clupea harengus*) off the Anglian coast of England. In addition to marine aggregates dredging, the following activities were also assessed: offshore renewables arrays; trawl and dredge fisheries; oil and gas pipelines; telecommunication cables; and dredge material disposal sites. The assessment found that marine aggregates extraction is generally not considered to lead to significant cumulative impacts requiring mitigation, as long as existing industry mitigation measures are continued, and given that the magnitude of the effect is often temporary. Of the other activities taking place in the region, trawl fisheries affect by far the largest area of potentially suitable habitat. Nevertheless, overall it is not thought that cumulative effects arising from all the activities combined are more than minor significant.

Abbreviations

ABPmer	ABP Marine Environmental Research Ltd
BAP	Biodiversity Action Plan
CIA	Cumulative Impact Assessment
ERM	Environmental Resources Management
ESFJC	Eastern Sea Fisheries Joint Committee
EIA	Environmental Impact Assessment
ICES	International Council for the Exploration of the Sea
IFCA	Eastern Inshore Fisheries and Conservation Authority
IHLS	International Herring Larvae Survey
JNCC	Joint Nature Conservation Committee
MAREA	Marine Aggregates Regional Environmental Assessment
MES	Marine Ecological Surveys
MMO	Marine Management Organisation
MMG1	Marine Minerals Guidance 1
NERC	Natural Environment and Rural Communities
ODPM	Office of the Deputy Prime Minister
PIZ	Primary Impact Zone
RAG	Regulatory Advisors Group
SIZ	Secondary Impact Zone
SSC	Suspended Sediment Concentrations
VMS	Vessel Monitoring System
%	Percent
km^2	Kilometre(s) squared
mg/l	Milligram(s) per litre

Assessment of Cumulative Impacts on Spawning Herring from Marine Aggregates Extraction in the Anglian Region

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1. Introduction

As part of the Marine Aggregate Environmental Impact Assessment (EIA) Working Group, ABP Marine Environmental Research Ltd (ABPmer) was commissioned by the British Marine Aggregate Producers Association (BMAPA) to undertake a cumulative impact assessment (CIA) of the effects of marine aggregates dredging and other projects and activities on spawning Atlantic herring (*Clupea harengus*) off the Anglian coast of England. Three other English dredging regions have been assessed by other members of the EIA Working Group (Environmental Resources Management (ERM), Fugro Emu and Marine Ecological Surveys (MES)).

As a demersal spawning fish species, Atlantic herring are considered to be sensitive to activities affecting the seabed which they preferentially use for spawning; including marine aggregates dredging. Atlantic herring are designated as a UK Biodiversity Action Plan (BAP) priority species, they listed in the commercial marine fish BAP, and are also considered to be a species of principal importance for the conservation of biodiversity in England under the2006 Natural Environment and Rural Communities (NERC) Act. They are furthermore viewed as being of commercial importance.

This report has been prepared based on a detailed method statement developed by the EIA Working Group, in consultation with the Marine Management Organisation (MMO) and the Regulatory Advisors Group (RAG) (Reach *et al.*, 2013) – 'Screening Spatial Interactions between Marine Aggregate Application Areas and Atlantic herring Potential Spawning Habitat – A Method Statement'. Following submission of draft CIAs in August 2013, comments were received from the Marine Management Organisation (MMO) and its advisors, and this final report takes account of the relevant change requests.

This report is intended to supplement the fish ecology impact assessment undertaken for the Anglian Offshore Marine Aggregates Regional Environmental Assessment (MAREA) (Emu, 2012).

Please note that ABPmer have also been commissioned to present the same type of assessment for sandeel impacts. The sandeel CIA is presented in a separate report.

The report is structured in the following way:

Section 2: Background to the Anglian Dredging Region;

Section 3: Methodology;

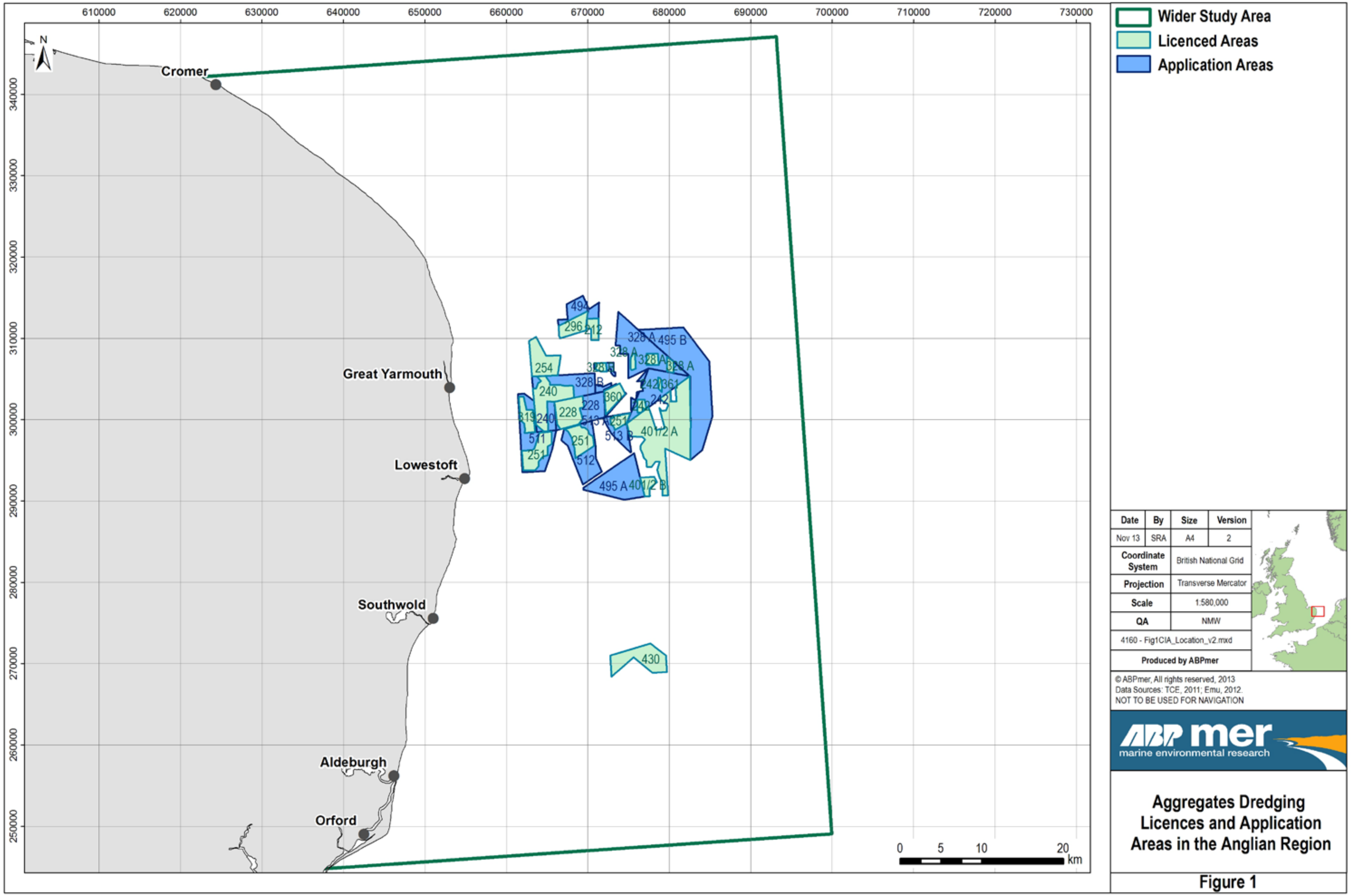
Section 4: Baseline and Screening Information; and

Section 5: Cumulative Impact Assessment.

2. Background to the Anglian Dredging Region

The marine aggregate licences within the Anglian / East Coast region of England have been an important source of aggregates for over 40 years. Offshore, the sands and gravels are of particularly high quality and, as a result, the supply of marine aggregates forms an important contribution to fulfilling local demand as well as supplying the markets of the south-east and the near continent (Emu, 2012).

The Anglian region currently has a total of 13 production licences for both sand and gravel, principally for use in the construction industry (BMAPA, 2013); these are being worked by five aggregates companies. Furthermore, several application / prospecting areas are currently being pursued. These areas are shown in Figure 1 below, which also depicts the extent of the MAREA region.


Wider Study Area
Licenced Areas
Application Areas
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Cromer
Great Yarmouth
Lowestoft
Southwold
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Orford
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© ABPmer, All rights reserved, 2013
Data Sources: TCE, 2011; Emu, 2012.
NOT TO BE USED FOR NAVIGATION
ABP mer
marine environmental research
Aggregates Dredging Licences and Application Areas in the Anglian Region
Figure 1

3. Methodology

As outlined previously, the assessment approach and pathways to be applied for this Cumulative Impact Assessment (CIA) are outlined in the method statement by Reach *et al.* (2013). However, the impact evaluation methodology *per se* is to follow the respective MAREA methodology. Hence, the MAREA methodology applied by Emu for the 2012 Anglian MAREA is now firstly outlined in Section 3.1, before the Reach *et al.* (2013) CIA approach is briefly discussed in Section 3.2.

3.1 Cumulative Impact Assessment Structure Applied in the Anglian MAREA (Emu Methodology)

The Anglian MAREA assessed the cumulative and in-combination impacts of all aggregate dredging and other activities at the Anglian regional level. These types of assessment were defined as follows (Emu, 2012, Vol1, p.3.1):

- Cumulative: Impacts that arise from multiple marine aggregate extraction activities within a region and/or sub-region.
- In-combination: The total impacts of all industrial sectors operating within the same region in the context of natural variability or trends[1].

Emu's CIA methodology consisted of eight steps, which are as follows:

Step 1: Conceptualise effect-receptor relationship

Step 2: Quantify 'magnitude of effects'

Step 3: Map overlap between effects and receptors

Step 4: Characterise effect-receptor interactions

Step 5: Quantify 'sensitivity of receptor'

Step 6: Assign cumulative impact significance and map regionally and sub-regionally

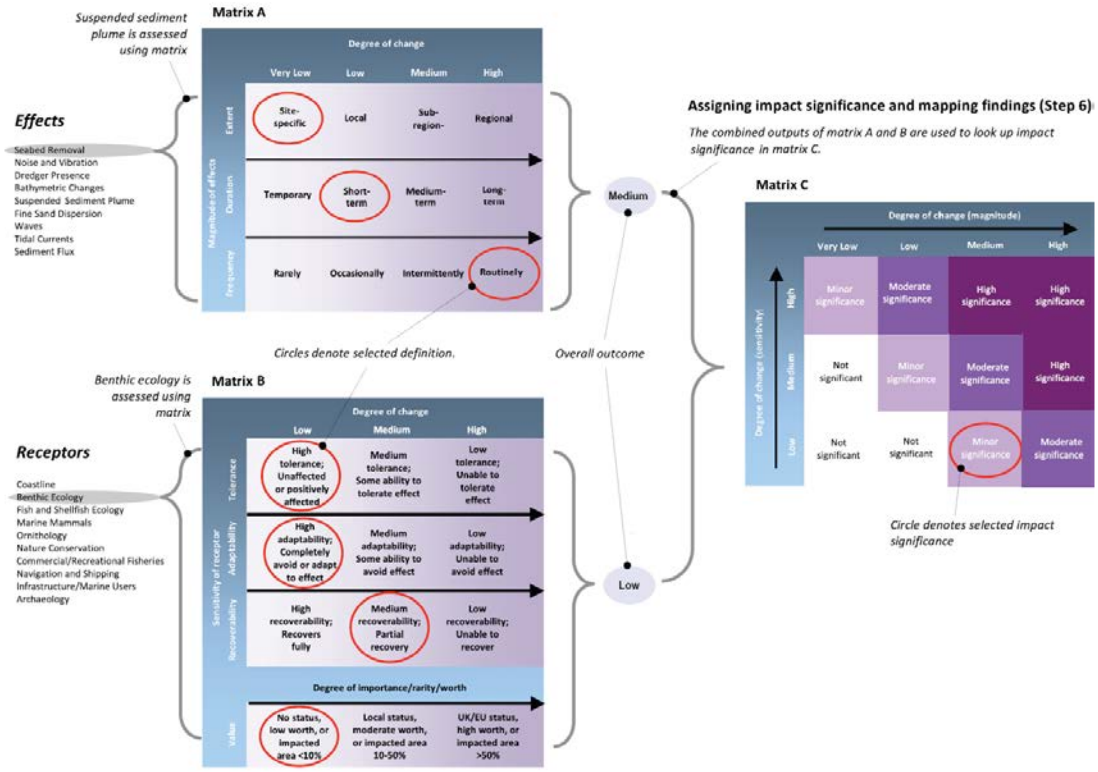
Step 7: Determine in-combination impacts

Step 8: Conclusions and recommendations

[1] Please note that the definition of 'in-combination' applied for the MAREA should not be confused with the 'in-combination' definition in relation to the Conservation of Habitats and Species Regulations 2010 (as amended), where 'in-combination' effects relate to those combined effects of plans or projects which could have significant effects on European designated sites or features.

With regard to Step 6 (Assigning Impact Significance), significance was defined as reflecting 'the level of importance placed on the impact in question and usually where it is acceptable to society'. For the purpose of determining significance, 'magnitude of effect' is assigned one of the following four categories; Very Low, Low, Medium and High (see matrix A in Image 1 below, which also shows an illustrated example), where 'sensitivity of receptor' is assigned either Low, Medium and High (see matrix B). A further matrix (C) combines the outcomes from the 'magnitude of effects' and 'sensitivity of receptor' matrices (A and B) to assign cumulative impact significance. Definitions of significance were as follows:

- Not significant Impacts that, after assessment, were found to be not significant in the context of the MAREA objectives;
- Minor significance Impacts that warrant the attention of particular stakeholders but no action is required if impacts can be controlled by adopting normal good working practice;
- Moderate significance Impacts that should be recognised and addressed in consultation with particular stakeholders; and
- Major significance Impacts that are not environmentally sustainable and compromise the continuation of extraction activity in the region/sub-region.

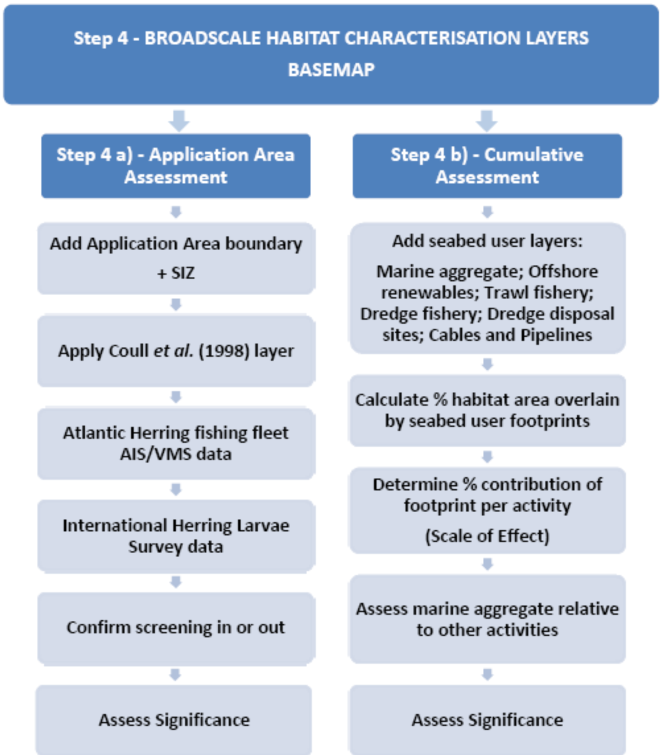


(Source: Emu, 2012, Figure 3.3)

Image 1. Illustrated Example of Assigning Magnitude and Sensitivity Including Assigning Impact Significance and Mapping

3.2 Cumulative Assessment Approach

A detailed description of the iterative steps which are to be applied to the Spawning Herring CIA was provided by Reach *et al.* (2013), and summarised in a chart which was re-produced below in Image 2. Step 4b describes the CIA approach, whereas Step 4a applies to the worked EIA approach (which is no longer presented). Please note that Steps 1 to 3 relate to screening and mapping levels which underpin this assessment, and which are discussed in the baseline section.



(Source: Reach *et al.*, 2013, Figure 5)

Image 2. Screening Levels to Enable Application Area and Cumulative Assessment Between Marine Aggregate Application Areas and Atlantic Herring Potential Spawning Habitat

In summary, relevant activities are mapped, and overlapped with seabed and percentage contribution of footprint calculated (at a regional scale). The cumulative impacts are then assessed, and marine aggregates related to the following activities:

- Offshore renewables arrays;
- Trawl fisheries;
- Dredge fisheries;
- Oil and gas pipelines;
- Telecommunication cables; and
- Dredge material disposal sites.

It is worth noting that MES, in cooperation with EIA working group members, undertook a confidence assessment on each of the data layers described in this document (MES, 2013); conclusions reached are summarised in the baseline section of this report (see Section 4).

Within an aggregate assessment, two impact zones are considered; these are defined as follows. The boundary of the Primary Impact Zone (PIZ) is understood to coincide with that of the marine aggregates licence and application areas. Building on the Anglian MAREA (Emu, 2012), the Secondary Impact Zones (SIZs) are defined as those areas, wherein there could conceivably be an indirect impact due to either the suspended sediment released during dredging (causing plumes or changes in particle size distribution), or the screening undertaken by some dredgers (potentially creating bedforms). Particle size distribution changes could be observed as far as 4km away from a dredger, whereas it is thought that bedforms could occur as far as 2.5km distant from dredging activities. High suspended sediment concentration plumes exceeding 50mg/l are generally not observed further than 400m away from a dredging vessel (HR Wallingford, 2010). These zones were modelled for the Anglian MAREA, and a maximum extent drawn around the zones defined by HR Wallingford[2] to determine the maximum SIZ extent for the purpose of this CIA. This is depicted in the relevant figures of this report (Figures 2 and 4 below).

As mentioned in the introduction to this report, comments on the draft CIA reports produced based on this methodology (and also for sandeel) were received by the EIA working group in early September. A clarifying meeting was subsequently held between regulators and selected members of the working group on 19 September 2013. The key points agreed were as follows (quoting directly from MMO, 2013a):

a) *'Heat maps with low, medium and high boundaries will be used instead of the preferential/marginal habitat maps when screening Herring potential spawning habitat and Sandeel habitat in and out at a regional scale, and for the assessment of potential regional exposure resulting from site specific, cumulative and in-combination pressures;*

b) *The East Channel Region Herring spawning methodology will not be used as test of the Herring Potential Spawning Habitat Assessment methodology as it is not comparable;*

c) *The proposed worst case scenario (all suitable habitats present in all licence areas being impacted) is appropriate rather than adopting a realistic worst case scenario. However, a more realistic scenario (based on historic dredged area derived from Electronic Monitoring System data) could usefully be added to provide added context;*

2 And ABPmer – three of the licence areas in the Anglian dredging block were subject to re-modelling in 2013 (namely Areas 240, 242 and 328 A), due to changes in dredging extent, and ABPmer consequently determined new, larger, SIZ extents.

d) *There is no requirement to undertake an assessment of possible direct effect pathways and resultant impacts on sandeel as a result of entrainment – this to be addressed in site specific Environmental Impact Assessment;*

e) *An update meeting has been scheduled at 4-4.30pm on 10 October 2013; and*

A target of the end of October was agreed for formally signing-off the revised methodologies and final assessments.'

The agreed actions from the follow up meeting on 10 October 2013 were as follows (quoting directly from MMO, 2013b):

a) *EIA WG to clearly signpost IHLS methodology from the appendices in the main report;*

b) *Cefas to confirm that the appendices provide enough information on the methodology used for the IHLS data (by 18 October 2013);*

c) *Cefas to provide regional narratives of where herring spawning occurs that can be considered and incorporated into the final assessment (by 18 October 2013);*

d) *MMO to contact IFCAs regarding the release of data where necessary for site specific assessments;*

e) *Cefas and NE to source DTU Aqua Data report (by 18 October 2013);*

f) *Cefas to provide additional information on the caveats detailed in response to Action e) from the 19 September 2013 meeting note (by 18 October 2013);*

g) *NE and Cefas to provide a steer on the level information required for the site specific herring spawning and sandeel habitat assessments (by 18 October 2013);*

h) *EIA WG to provide four case studies setting out the approach for assessing herring spawning and sandeel habitats at a site specific level.*

Cefas subsequently provided additional information on 18 October 2013 (Cefas, 2013); caveats and information provided in this document were included in this CIA as appropriate.

4. Baseline and Screening Information

This chapter presents baseline and screening information. Firstly, the extent of suitable herring spawning habitat is detailed in Section 4.1. Section 4.2 then summarises what other layers and information indicative of spawning herring presence are available for the Anglian region, before the screening outcome and confidence layer overlaps are presented in Section 4.3.

4.1 Spawning Herring Suitable Seabed Habitat

4.1.1 Introduction

Herring is a widespread and abundant pelagic fish species and there are several nominal stocks in the UK. Three of the stocks spawn in the North Sea (mostly) in August-September (Orkney-Shetland, Buchan and Banks) while in the eastern English Channel and southern Bight; a fourth stock, the Downs component (mostly) spawns during December to January (International Council for the Exploration of the Sea (ICES), 2012)). Whilst the different components mix outside the spawning season (and are fished together), each component is thought to have a high degree of population integrity (Payne, 2010 quoting Iles and Sinclair, 1982).

Herring are demersal spawners and spawn on gravel and similar habitats where there is a low proportion of fine sediment and well-oxygenated water (Ellis *et al.*, 2012). When spawning, herring preferentially select elevated sites such as the crests of seabed gravel ridges (Gubbay, 2003 quoting de Groot, 1980). Sediments where there is a low percentage of silt, and where seabed energy is high, leading to well oxygenated pore waters (Blaxter and Holliday, 1963; Marevelias *et al.*, 2000) are preferred. The depth of the spawning grounds is known to vary between stocks, but is thought to be in the range of 13-40m, although may be deeper where water depth allows (Skaret *et al.*, 2003). The size of spawning beds is typically relatively small; Reid *et al.* (1999) quote beds ranging from between 0.067km^2 and 1.39km^2 in size. The Irish Marine Institute meanwhile reported beds ranging from 0.001km^2 to a maximum of 170km^2 around the Irish coast, with most being below 0.1km^2 in size (O'Sullivan et al., 2013). The large beds reported by this study are unlikely to be actual continuous beds however, given the specific spawning habitat requirements of herring.

Despite their strict spawning habitat requirements, herring often exhibit low site fidelity, and the location of spawning beds may vary over time (Ellis *et al.*, 2012). As such, it is notoriously hard to define the spawning range of herring, rather than merely describing active spawning beds (Ellis *et al.*, 2012).

Based on the available evidence, Reach *et al.* (2013) determined that sediment classed as 'Gravel and sandy Gravel' on the Folk (1954) sediment classification scale should be viewed as 'preferred habitat', and 'gravelly Sand' as 'marginal habitat'. Aspects such as aeration and elevation are not to be considered in the analysis. As a consequence, not all areas described as suitable spawning habitat will actually be likely to support spawning herring.

4.1.2 Spawning Herring Suitable Habitat in the Anglian Region

The Anglian MAREA seabed sediment layers were used to create herring habitat layers in order to facilitate both the individual dredging area assessments, and the cumulative assessment.

This mapping revealed that the following areas were present in the Anglian MAREA region:

- Preferred spawning herring habitat: 560km^2, and
- Marginal spawning herring habitat: 1,770km^2.

The combined area of 'preferred' and 'marginal' spawning herring habitat accounts for 6.6% of the national seabed available to the Central North Sea and Southern North Sea spawning herring populations (see Section 2.1 of Reach *et al.* (2013) for the rationale behind the extent applied).

MES assessed a high confidence (3 out of 3) in the MAREA preferred and marginal habitat layers; however, as an indicator of spawning, a medium and low score was given to the two layers respectively (3 and 2 out of 5) (MES, 2013).

4.2 Indicators of Spawning Herring Presence in the Anglian Region

The subsequent section presents other data layers which are indicative of spawning herring presence, before other available information on spawning herring presence in the Anglian region is summarised (Section 4.3.2).

4.2.1 Overlap with other Spatial Information Indicative of Herring Spawning

Several spatial layers other than the habitat layers described above are available for the Anglian region which might be indicative of spawning herring presence.

Firstly, a herring fishery is present (according to an Eastern Sea Fisheries Joint Committee (ESFJC) mapping project[3]) in the zone immediately adjacent to the Anglian coast (within 2 to 3km of the coast). This is shown in Figure 2 and could be indicative of herring spawning, as fishermen apparently often target herring on migration to their spawning grounds (Ron Jessop, Eastern IFCA, pers. comm. with Ian Reach of MarineSpace). Figure 2 also shows a layer which resulted from a 1998 a project led by the fisheries agencies, whereby fish sensitivity areas were mapped (i.e. spawning and nursery areas) for the main commercial fish species (Coull *et al.* (1998)[4]). This indicates a (likely Downs) spawning close to the shore.

Figure 3 displays both the combined point data and interpolated map for International Herring Larvae Survey (IHLS) larvae data[5] (based on surveys spanning from 2002 to 2011). This shows that there is limited IHLS survey coverage; with surveys only covering the outer edges of the MAREA study area. However, two survey stations in the north east and east of the MAREA

---

3 This 2010 mapping project aimed to describe, using best available data and fishermen's knowledge, the extent of the main fisheries within the ESFJC District. Please note that SFJCs are now called 'Inshore Fisheries and Conservation Authorities' (IFCAs).

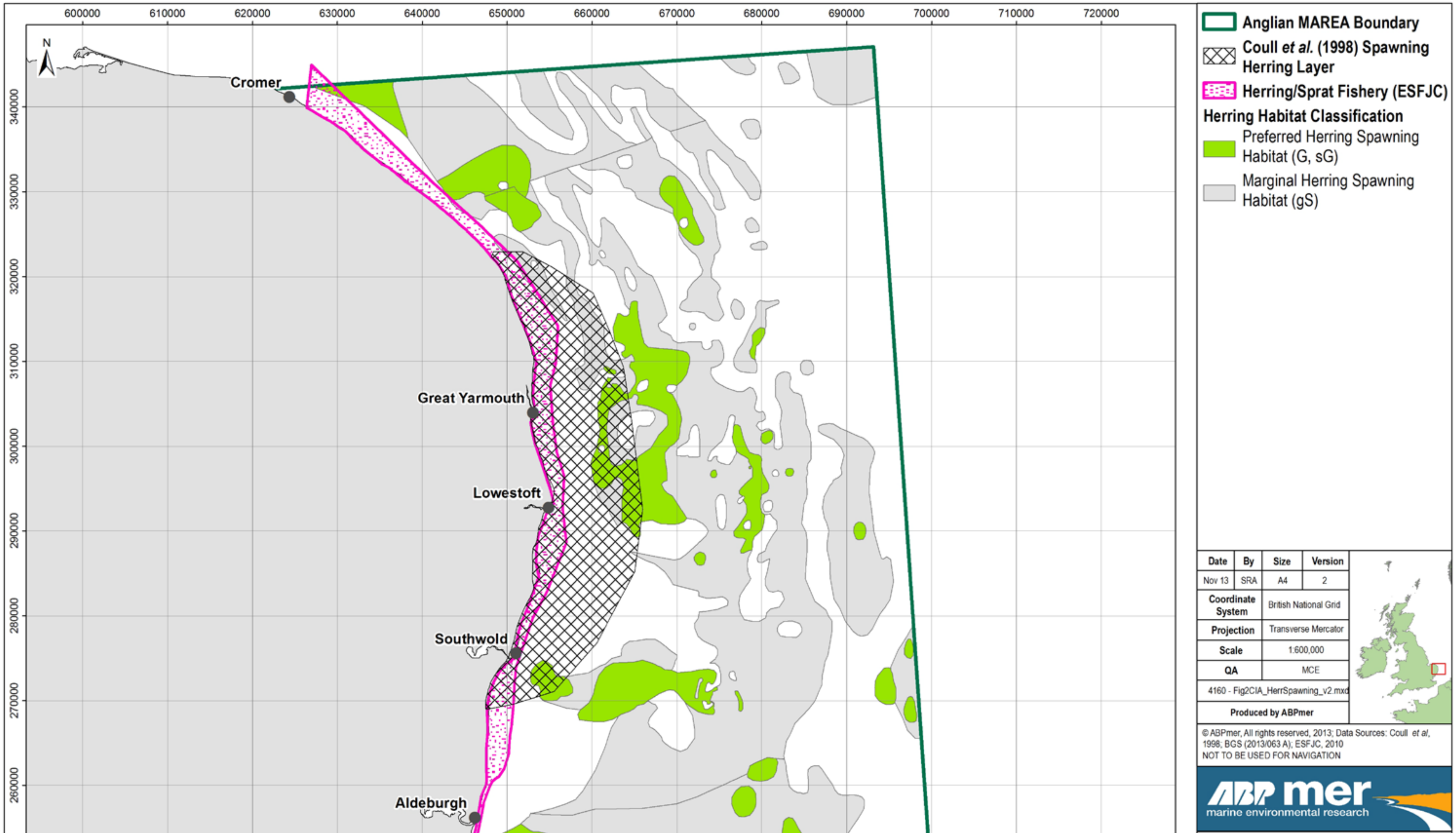
4 This identified spawning areas around England. Data was based on the collated distribution of eggs, larvae, young and commercially sized fish, seabed sediments and acoustic visualisation techniques (see MES (2013) for more detail). It remains unclear, whether the zone drawn straddling the East Anglian coastline is an actual spawning ground (and if so of what intensity) or a historic spawning ground, as the source data underlying Coull *et al.* has not been available for analysis.

5 IHLS aims at the very young stages of freshly hatched herring in the vicinity of spawning areas. Point data was obtained by the EIA working group, and interpolated to arrive at an abundance map. However, it is important to note that there is limited IHLS data coverage; with surveys not reaching the majority of the Anglian dredging block.

recorded no larvae, and the three to the south east only recorded low numbers. Generally, the surveys in the vicinity of the wider study area recorded relatively low numbers when compared to stations in the English Channel, where maximum numbers were observed. It is also worth noting that the 11mm size class does include the phase where larvae start moving away from their spawning grounds; hence, those larvae observed in the vicinity of the wider study area may not have originated from within the study area.

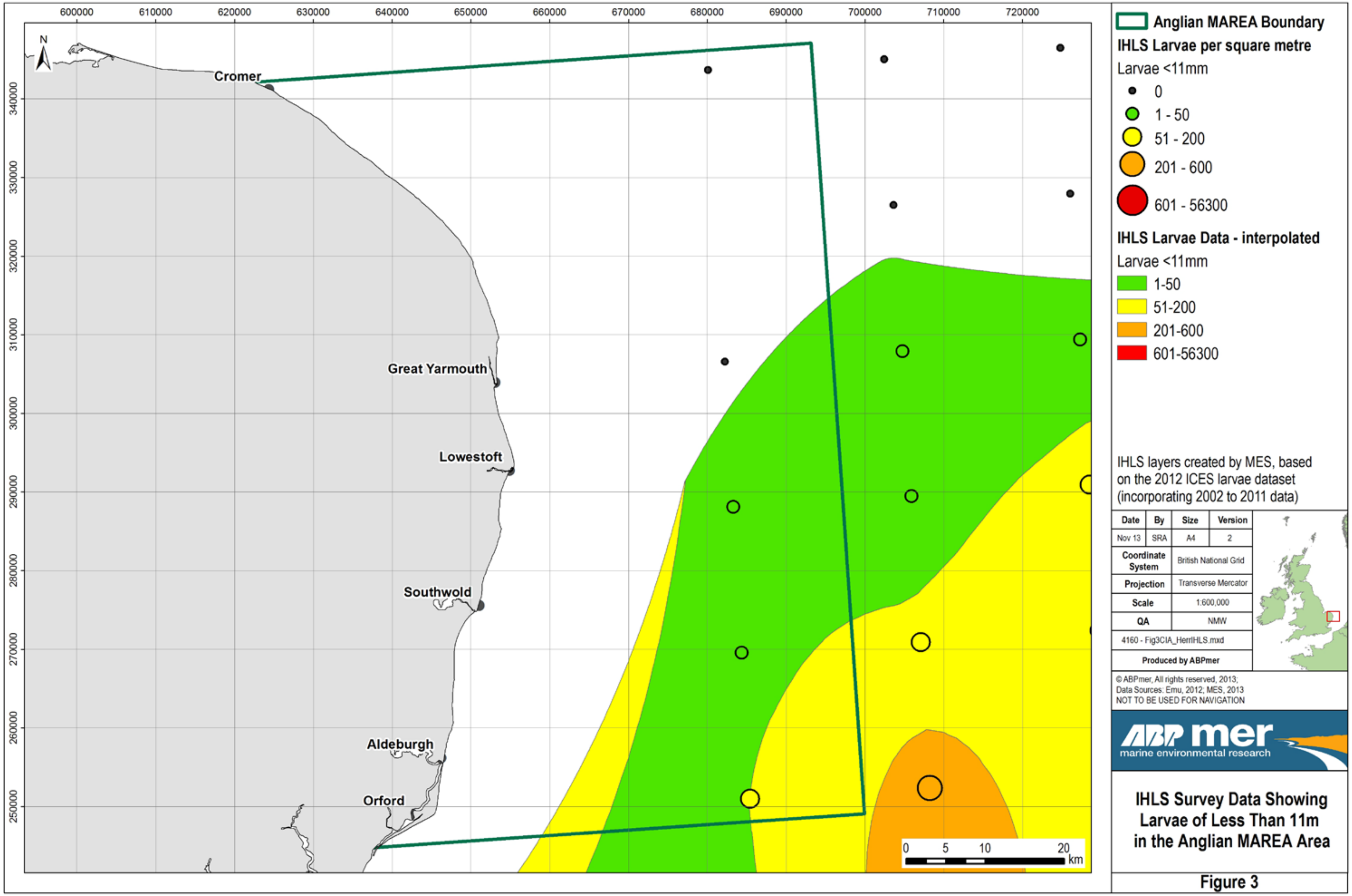
It is worth noting that MES assessed the confidence and 'indicativeness of herring spawning' for these three layers as follows:

- IHLS: high confidence (3 out of 3), very high indicator (5 out of 5);
- Coull *et al.* (1998): low confidence (1 out of 3), medium indicator (3 out of 5); and
- ESFJC: low confidence (1 out of 3), medium indicator (3 out of 5).



Herring Spawning Seabed Habitat and Overlap with other Layers Indicative of Spawning Activity

Figure 2



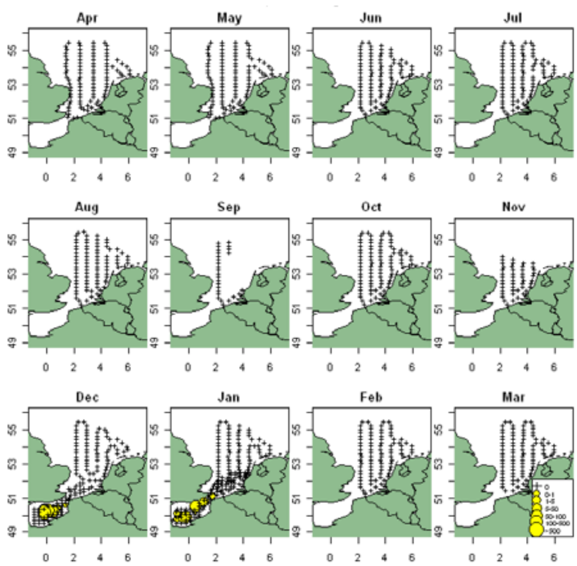
IHLS Survey Data Showing Larvae of Less Than 11m in the Anglian MAREA Area

Figure 3

4.2.2 Information on Spawning Herring Presence from other Sources

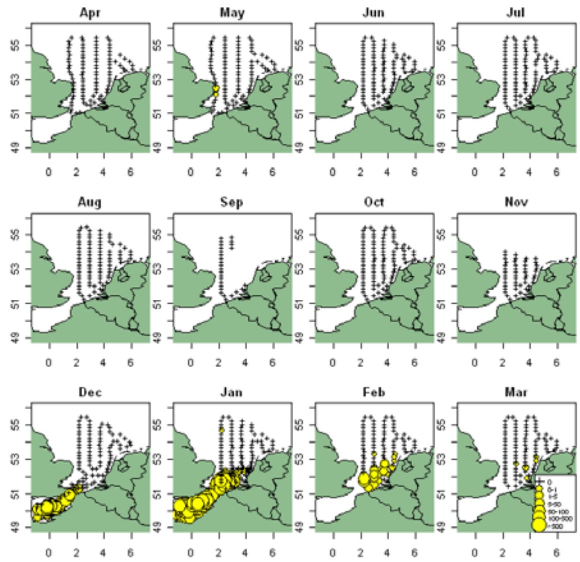
Further information on spawning herring presence in the Anglian region has been gleaned from the literature relating to larvae surveys (in addition to those by the IHLS).

A recent Dutch study (van Damme *et al.*, 2011) undertook twelve monthly ichthyoplankton surveys between April 2010 and March 2011 in the southern North Sea. During the May and April surveys, nearshore stations were also sampled along the Anglian coast. During the other months, including the crucial spawning months of December and January, only stations further offshore were surveyed. No yolk-sac herring larvae (i.e. youngest) were observed near the Anglian coast in any month (with large concentrations observed in the English Channel only) (see Image 3). Very small numbers of individuals (one to five) were observed at two to three nearshore stations for non-yolk sac and bent notochord stage herring larvae in the May surveys (see Image 4 for non-yolk sac stage). These larvae could have moved from the recognised significant spawning grounds in the English Channel, as (following the yolk-sac phase), non-yolk sac larvae move away from spawning grounds with the water stream (mostly to the coastal areas in the eastern southern North Sea) (van Damme *et al.*, 2011). It could also be indicative of (limited) spring spawning in the region.



(Source: Figure 1a, Appendix A, van Damme *et al.*, 2011)

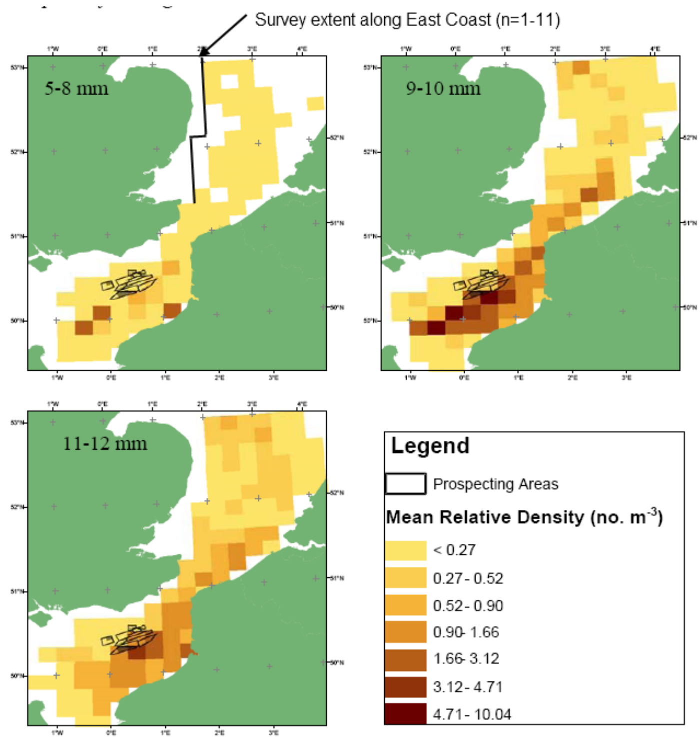
Image 3. Spatial and Temporal Distribution of Yolk Sac Herring Larvae



(Source: Figure 1b, Appendix A, van Damme *et al.*, 2011)

Image 4. Spatial and Temporal Distribution of Non-yolk Sac Herring Larvae

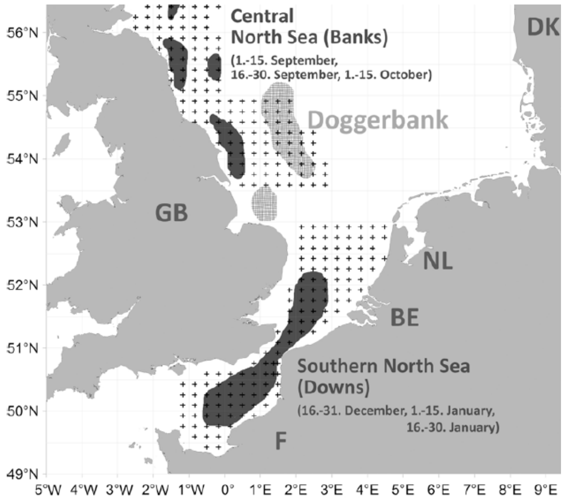
A 2003 reanalysis of the Eastern Channel herring larvae surveys undertaken between 1998 and 2002 indicates that 5-8 mm larvae, which are thought to most closely correspond with the positions of spawning grounds, may have historically been present offshore of the Anglian coast (although in low numbers – as seen in Image 5) (Mills *et al.*, 2003).



(Source: Mills *et al.*, 2003, Figure 3; survey extent drawn by ABPmer)

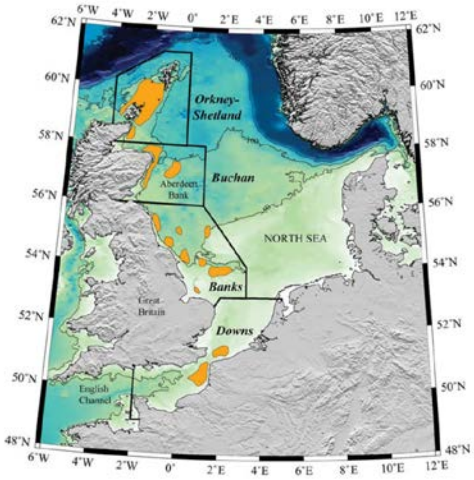
Image 5. Distribution of Mean Relative Herring Larvae Density at Three Length Classes, Combining Years 1998-2002

It is also worth noting that the seabed off the Anglian coast has never been identified as a significant herring spawning area in the literature. Instead, on the English coast, such areas have been identified in the English Channel, off the Wash (mostly historic), off England's north-east coast and on Dogger Bank (for example, Payne, 2010; Schmidt *et al.*, 2009) – see also Images 6 and 7 below.



(Source: Schmidt *et al.*, 2009)

Image 6. Recent (Dark Grey) and Historic (Light Grey) Spawning Grounds of North Sea Herring (Sampling Periods in Brackets); Small Crosses Indicate Station Grid of International Herring Larval Survey



(Source: Payne, 2010)

Image 7. Map of the North Sea with Recognised Spawning (Approximate Boundaries of the Areas Covered by the International Herring Larval Survey Marked with Bold Lines.

4.3 Screening Results / Confidence Assessment

The screening outcome (based on the confidence layers produced by MES) is now firstly presented for the Anglian aggregates areas, before activity overlap with the same layers is presented for aggregates and other activities which could lead to cumulative effects.

4.3.1 Screening Outcome

In order to determine whether any of the aggregates areas in the Anglian MAREA region could be screened out of the CIA, the outcome of the screening exercise is presented in a heat diagram[6] in Figure 4, based on the MES (2013) confidence assessment.

The score arrived at at any given location is the sum of the following layers: IHLS, sediment type, ESFJC, Coull *et al.* (1998) and VMS. Please note that VMS data (not previously discussed) is split into demersal gear types and pelagic gears, where pelagic gears target herring as well as many other species. Thus, VMS data can be interpreted as providing a low (MES score of 2 out of 5) indicator to herring spawning grounds. VMS data was scored as high (3 out of 3) for confidence in the data (MES, 2013).

6 i.e. a colour gradient map where the larger values are represented by a darker colour to denote a greater number of variables

Figure 4 presents a simplified categorisation of 'low', 'medium', 'high' and 'very high', as well as the more detailed numerical scale of 1 to 16. This heat map, which was generated from overall confidence scores, is not necessarily indicative of spawning grounds; rather, higher confidences indicate that more layers of data were available for that particular area (irrespective of data content). It should not be assumed to be directly related to spawning activity.

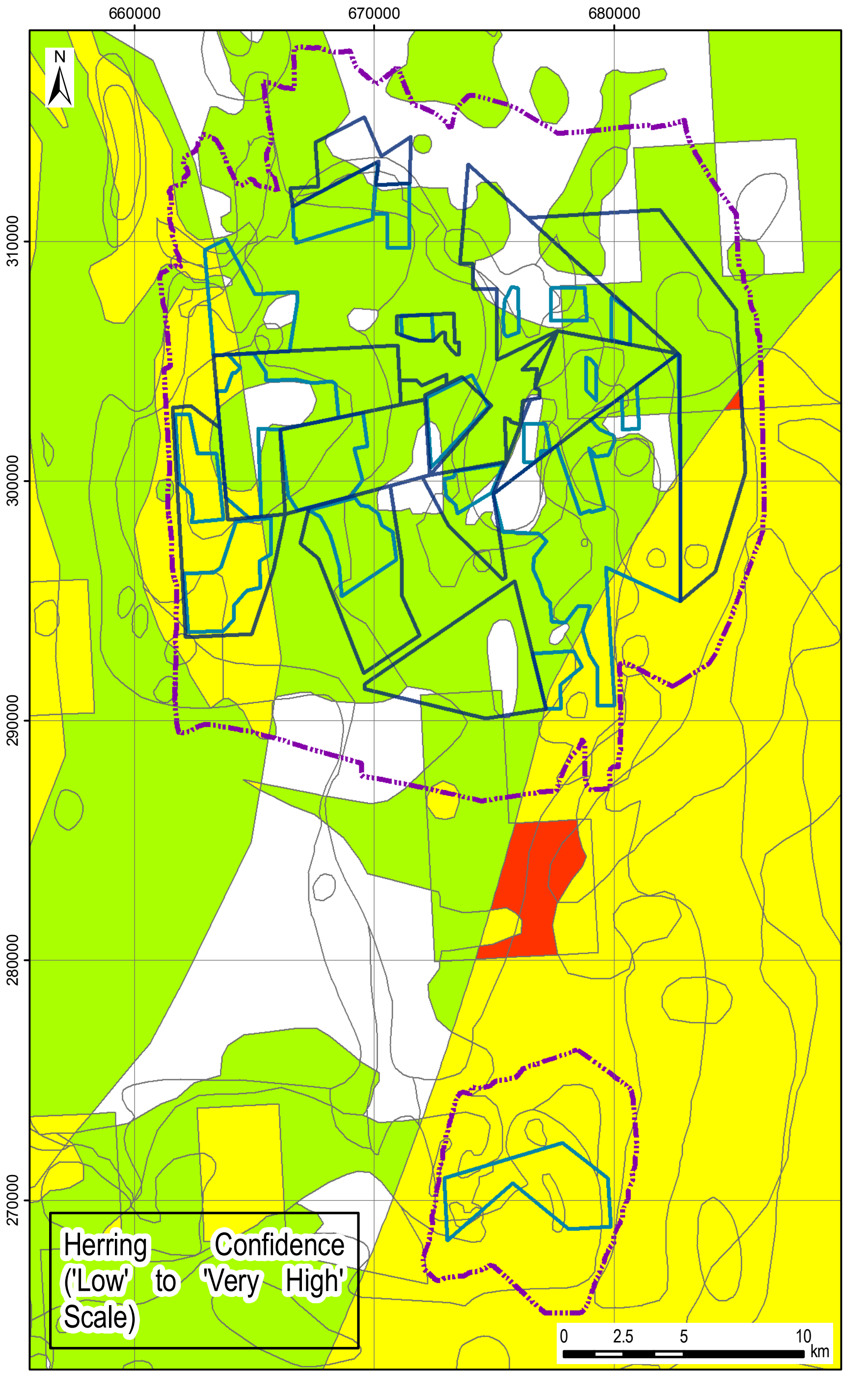
Figure 4 and Table 1 demonstrate that no 'very high' areas are present in / around the Anglian dredging areas. In fact, no such areas were found anywhere in the wider study area, or nationally; however, this category was included on the map legends to account for the maximum possible data layer score. Furthermore, only very small areas of 'high' confidence are present.

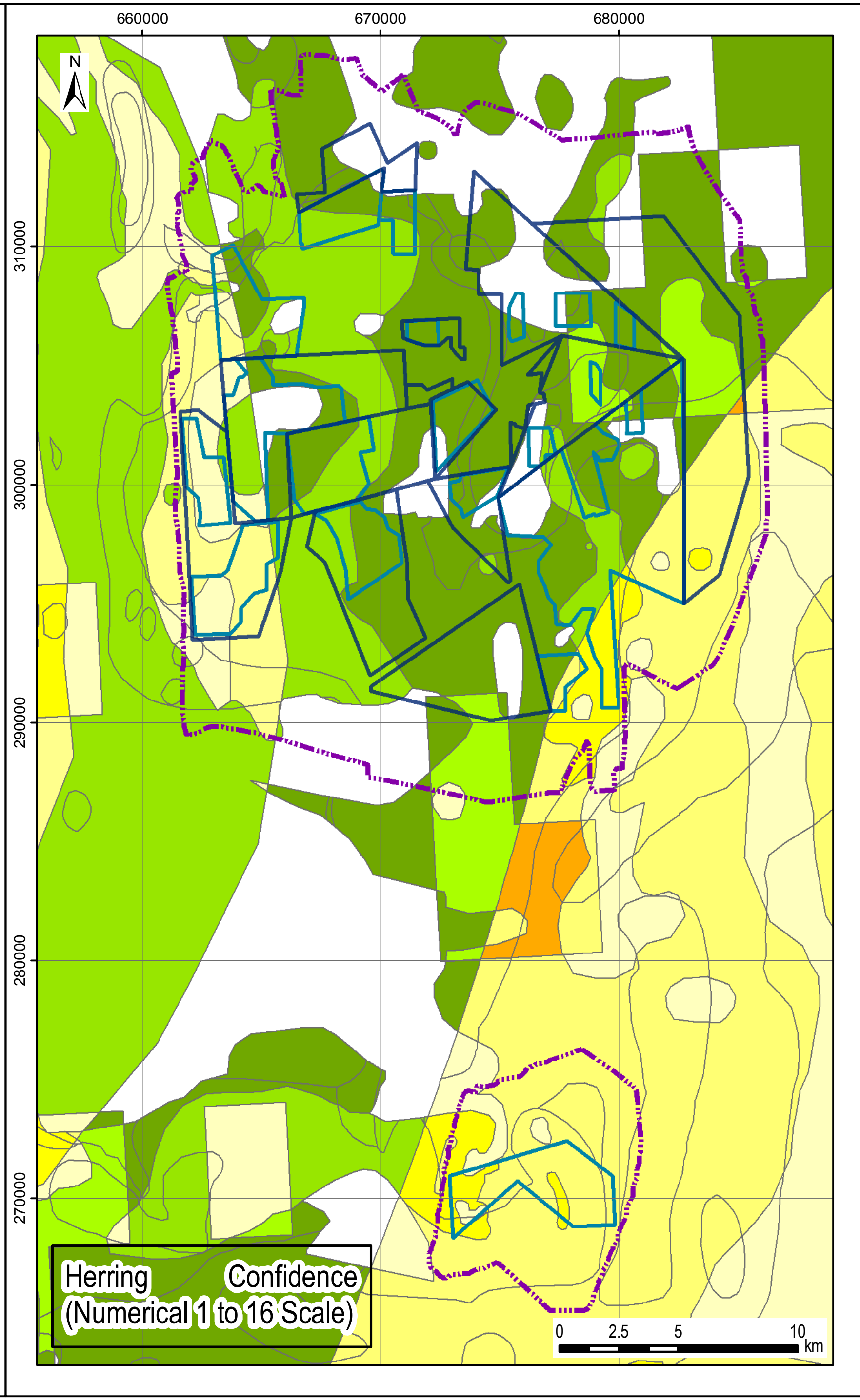
Table 1. Overlap of Anglian Aggregates Areas with Confidence Layers

Area	Predominant Confidence Category (Word)	Predominant Confidence Category (Number)	Area	Predominant Confidence Category (Word)	Predominant Confidence Category (Number)
212	Low	2 & 3	401/2 A	Low	2 & 3 (some 5, 8 & 0)
228	Low	2 & 3 (some 0)	401/2 B	Low & Medium	2 & 7
240	Low	2 & 3 (some 5 & 0)	430	Medium	7 (some 8)
242	Low	2 & 4 (some 0)	494	None & Low	0 & 2
254	Low	2 & 3 (some 5, 6 & 0)	495 A	Low	2 (some 0)
296	Low	2 & 3	495 B	Low	2 & 4 (some 5, 8 & 0)
328 A	None & Low	0 & 2	511	Medium	5 & 6
328 B	Low	2	512	Low	2 & 3
328 C	Low	2	513 A	Low	2 (some 0)
361	Low	2	513 B	Low	2 (some 0)

Regarding spatial interaction with aggregates activity, all the Anglian dredging areas overlap with at least one layer potentially indicating spawning herring grounds. Of the (sub-) areas, 15 mostly or completely overlap with the 'low' categorisation, one with near-equal areas of 'low' and 'medium', two with 'medium' and two with 'none' and 'low''[7]. Thus, all the Anglian aggregates areas and their SIZs were screened into this CIA.

7 Numerical scores of '8' represent a IHLS score of 5 and a 'preferred' seabed habitat score of 3. Overall scores of '7' reflect the same IHLS score, but a lower 'marginal' habitat score of 2. A score of 6 represents 3 points for overlap with the Coull *et al.* (1998) layer, and a score of 3 for habitat. Inshore, 5 represents the same, but with only 2 for habitat. Offshore, 5 reflects a score of 5 for IHLS data overlap only. A score of 4 represents a VMS overlap (scoring 2) coinciding with a marginal habitat score (2). Finally, scores of 2 and 3 reflect overlap with marginal and preferred habitat layers respectively. For further explanation of the scoring system, see MES 92013.





Application Areas
Licenced Areas
Maximum Footprint of SIZs

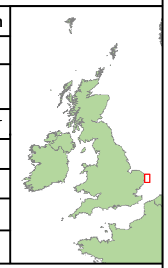
Herring Confidence

- Very High
- High
- Medium
- Low
- No Data

Herring Confidence (1-16 Scale)

- 0 (No Data)
- 1 (Low)
- 2 (Low)
- 3 (Low)
- 4 (Low)
- 5 (Med)
- 6 (Med)
- 7 (Med)
- 8 (Med)
- 9 (High)
- 10 (High)
- 11 (High)
- 12 (High)
- 13 (Very High)
- 14 (Very High)
- 15 (Very High)
- 16 (Very High)

Date	By	Size	Version
Dec 13	SRA	A4	2
Coordinate System	British National Grid		
Projection	Transverse Mercator		
Scale	1:310,000		
QA	NMW		
4160 - Fig4CIA_HerringConf_v3.mxd			
Produced by ABPmer			



Data Sources: MES, 2013; TCE, 2013
NOT TO BE USED FOR NAVIGATION

ABP mer marine environmental research

Herring Confidence Heat Maps

Figure 4

4.3.2 Overlap of Activities with the Confidence Layers

The percentage overlap of the activities listed in Section 3.2 and the spawning herring confidence layers are given in Table 2[8], and a visual depiction of the overlap is provided in Figure 5. The percentages relate to the total area of the combined high/medium/low confidence layer coverage in the Anglian MAREA region.

The table demonstrates that marine aggregates rank fourth when overlapping activity/project footprint with any confidence layer (bearing in mind however that there is some double counting in this data, as some Application Areas contain current Licence Areas – in total this overlap accounts for 65km^2, or 1.5% of the total confidence layer area). By far the largest overlap is seen for demersal trawling[9], accounting for 0.4% of 'high' confidence areas, 38% of the 'medium' confidence areas, and 19% of the 'low' confidence areas. Trawling is followed by windfarm licence areas – this relates to the Round 3 licence area, wherein windfarms could be developed; the first of these, East Anglia ONE is currently going through the planning stages and only very marginally overlaps with the MAREA extent (which constitutes the boundary of this CIA). Disposal sites account for some 9.2% in total. The overlap of the current and potential marine aggregates dredging licence areas with the herring confidence layers amounts to 0.0009% of the 'high' category areas present, 2.3% of the 'medium' areas, and 6.5% of the 'low' grounds present. The footprints of other activities, most notably cables and pipelines and operating windfarm turbines, make relatively small contributions.

Trawler fishing and the Round 3 windfarm licence area frequently overlap with other pressures and therefore to arrive at a realistic cumulative total, the area not touched by any activity was calculated. It was found that some 27% of the (high/medium/low) confidence area showed no overlap with any of the cumulative activities or projects mapped.

It should be noted however that for several of the activities, the footprints applied represent very conservative / unrealistic worst case scenarios. For example, none of the dredging areas would be dredged across their whole extent at any one time. Similar limitations apply to disposal sites and also trawler fishing. Furthermore, they represent potential zones of impact, and not certain habitat change.

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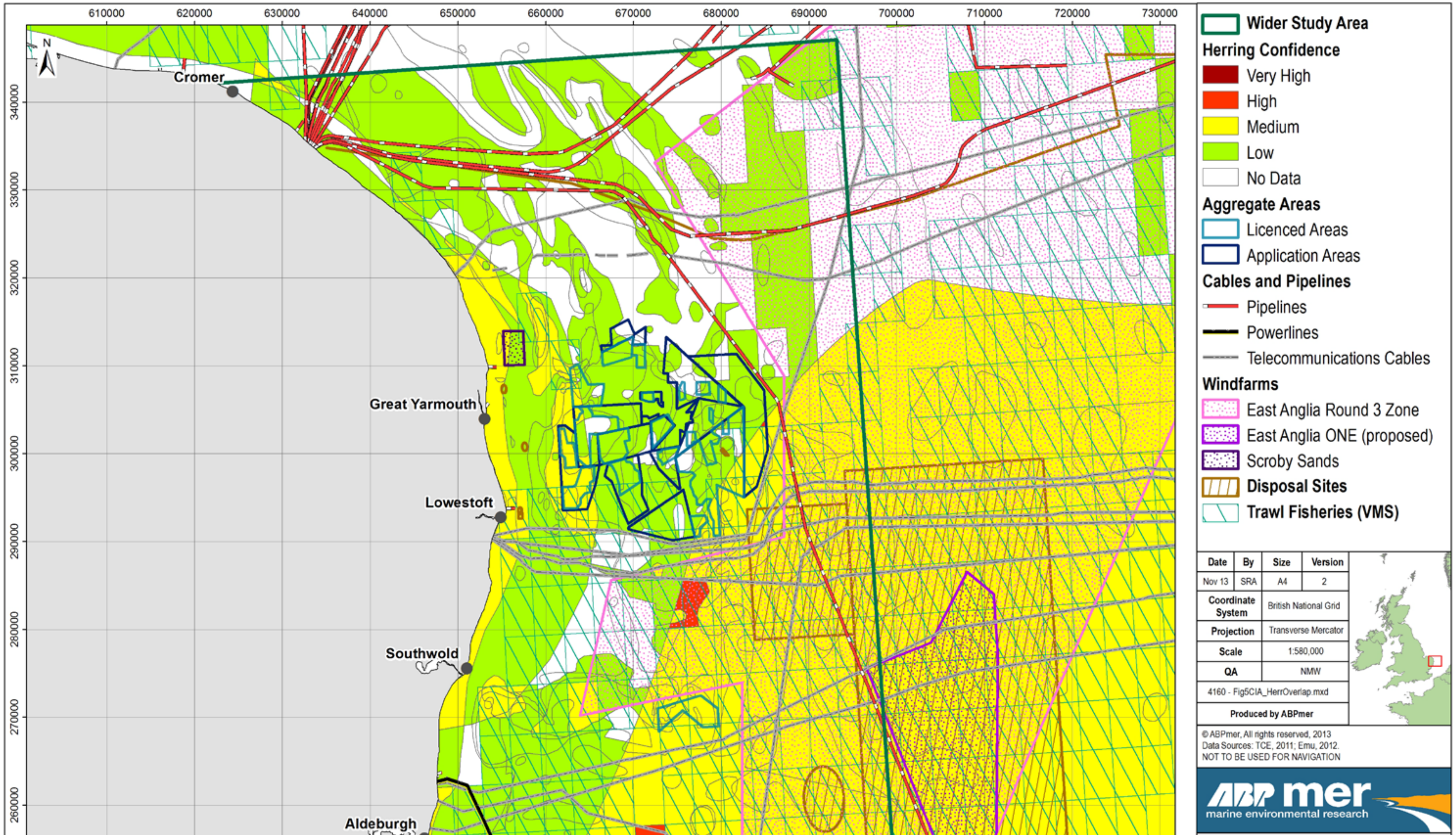
8 Where available, ERM used the exact footprints to establish the spatial interaction. Where a seabed user footprint could only be established in outline (the standard footprint), a generic approach to establishing a realistic worst case detailed footprint was adopted to ensure that the full spatial footprint of interaction with the relevant grounds could be established. Therefore, where a standard footprint has been used, the worst case interaction was established.

9 Please note that the calculations were based on a merged 2007 to 2011 VMS layer mapped according to ICES sub-rectangles. Also, no dredge fishery was identified anywhere in the MAREA region according to VMS.

Table 2. Percentage Overlap of Cumulative Activities with Herring Confidence Layers

Confidence Score	Cables and Pipelines				Fisheries		Disposal Sites	Windfarms				Aggregates		Cumulative Total
	Pipelines	Power Cables	Telecommunications Cables	'Worst-Case' Proposed Power Cables	Demersal Trawling	Fisheries Dredging	Disposal Sites	Operating Windfarm Turbine Footprint	Operating Windfarm Licence Areas	Proposed Windfarm Sites - Indicative Turbine Footprint	Windfarm Licence Areas Proposed	Current Licence Areas	Application Areas	
High	0	0	0	0	0.39	0	0	0	0	0.0007	0.39	0	0.009	0.40
Medium	0.0008	0	0.0004	0.0007	38.4	0	9.01	0.0006	0.06	0.06	25.59	1.23	1.10	42.72
Low	0.004	0.0002	0.0002	0.0002	18.6	0	0.15	0.001	0.17	0.02	8.52	2.25	4.26	29.86



Spatial Interaction of Potential Herring Spawning Grounds and Cumulative Activities

Figure 5

5. Cumulative Impact Assessment

5.1 Introduction

The MMO and the RAG have 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 Marine Works (EIA) (Amendment) Regulations 2011. Reach *et al.* (2013) clarified that 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 PIZ:

- 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 SIZ:

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

In agreement with the MMO and RAG, the following pathways do not need to be assessed with regard to herring:

- Effects of sediment plumes on the larvae; and
- Entrainment of larvae and adults.

Furthermore, potential population level effects of marine aggregate dredging on Atlantic herring are not considered to be required to be assessed.

For the purpose of this CIA example, the scoped in pathways will be discussed under the following Anglian MAREA dredging effect headings:

1. Seabed removal;
2. Suspended sediments; and
3. Fine sand dispersion.

The following effects are not discussed:

- Vessel displacement;
- Noise and vibration;
- Bathymetric changes;
- Wave changes;
- Tidal current changes; and
- Sediment flux (proxy for sediment erosion and accretion).

Please note that 'recovery of habitat' is not a pathway per se, but is an aspect informing sensitivity, and is hence incorporated into the relevant pathways.

Prior to the assessments being undertaken, the value assigned to herring for the purpose of the assessments is briefly outlined. In summary, based on the MAREA methodology (see Image 1), herring has been assigned a **medium value** (with value being a function of importance, rarity and worth). This is due to herring being listed as a nationally important species with regards to biodiversity conservation (BAP and NERC). It is a widespread species which is considered as being commercially important; however, it is not thought to be extensively targeted by fishermen in the MAREA region[10]. Furthermore, with regards to available seabed area, the total herring spawning seabed area present in the MAREA region is less than 10% of the national total (6.6%; see Section 4.1).

The three effects scoped in for full impact assessment above are now assessed in turn. In each section, the cumulative impacts of aggregates dredging are firstly assessed, before the contribution of other activities is considered.

5.2 Seabed Removal

5.2.1 Impacts from Marine Aggregates Dredging

5.2.1.1 Impact commentary

Seabed removal by marine aggregates dredgers could lead to the direct removal of habitat, an alternation of the habitat structure, and the direct uptake of eggs in the PIZs of aggregates areas.

As previously mentioned, as demersal spawners, Atlantic herring show a preference for gravelly and sandy gravel seabed (and may also select 'gravelly sand'). They are also thought to preferentially select elevated sites such as the crests of seabed gravel ridges with relatively high flow velocities (Gubbay, 2003 quoting de Groot, 1980). The depth of spawning varies and is largely temperature dependent, but can range from 5 to 150m (Lambert, 1987). It is noteworthy that the depth of aggregate extraction in the MAREA region is typically at 15 to 40 metres below Chart Datum, and that worst case bathymetric changes in the licence and application areas are generally in the region of 2 to 4m, though could be up to 10m (see

10 'Small pelagics' accounted for 1.3% of the total landed value in 2006 (Walmsley and Pawson, 2007).

Appendix B to Emu, 2012). With regard to potential changes to tidal currents due to aggregate extraction in the Anglian MAREA region, the MAREA modelling found that, where localised dredging-related tidal current reductions are anticipated to occur, these are typically in the order of 5 to 10% (Emu, 2012; HR Wallingford, 2011). It is worth noting that flow speeds in the Anglian region are generally fairly high (HR Wallingford, 2011), and that related tidal current-induced bed shear stresses are equally relatively high throughout the region during normal tidal conditions; this leads to sand-sized material being mobile throughout most of the region (even gravel sized in some isolated areas during spring tide conditions) (ABPmer, 2013). Thus fine grained material deposited as a result of a plume or draghead seabed disturbance will be dispersed and generally kept in suspension.

The baseline information indicates that large proportions of the seabed within the Anglian MAREA region are theoretically suitable for herring spawning, although 'preferred habitat' occupies a relatively small area (560km^2 out of ca. 4,800km^2 – i.e. ca. 11% of the seabed area).

Table 2 shows that Anglian licence and application aggregates dredging areas directly overlap with some 8.8% of the high/medium/low confidence areas present in the MAREA region – however some 1.5% of that is double counted (due to licence areas being located in application areas), and the accurate total percentage is thus 7.3%.. It should however be noted that this represents an unrealistic worst case scenario, as relatively small percentages of licence areas tend to be dredged in any given year; for example, in 2009, only 17.7% of the overall area licensed in the Anglian region was dredged (BMAPA, 2009); whereas in 2012, 19.3% was dredged (BMAPA, 2013). On this basis, it may be more realistic to apply a conservative 'likely percentage of licensed area affected', which according to the last 10 years of annual BMAPA reports, would be around 20% (over the past 10 years, 18.1% of the Anglian licensed area was dredged on average). Applying 20% would mean that the combined area of suitable herring spawning habitat affected by aggregate dredging in any one year would be less than 1.5% of the regional total of 'preferred' and 'marginal' spawning herring habitat. Over the course of the licence, the full percentage could be affected. However, typically, significant proportions of licence areas are (hardly) ever dredged.

Available layers indicating herring spawning imply that, if spawning takes place in the region, intensity is likely to be fairly low.

Should spawning take place on the areas of suitable seabed within the PIZs of the dredging areas, and dredging coincide with the spawning season, then eggs would be taken up by the draghead in the area of active dredging, and consequently lost.

Herring which may have been spawning in a given area which is subject to dredging may not subsequently return to deposit more eggs (as groups of herring typically lay eggs together (Stratoudakis *et al.*, 1998)). Uncertainty exists with regard to recovery of habitat in this respect. However, it is assumed that recovery would be rapid should the same habitat type remain. Should a spawning ground however be completely abandoned for some reason, it has been shown that it can take up to 25 years for herring to re-colonise such grounds (Schmidt *et al.*, 2009).

Within the PIZ, seabed removal could potentially lead to a change in seabed habitat (structure), whereby the draghead either exposes bedrock, or finer layers of sediment. Bedrock, whilst not eminently suitable, could potentially be viewed as 'marginal' habitat, as herring have been observed as spawning on boulders (Dorel and Maucorps, 1976). Different orders of magnitude would be applied to the change of preferred habitat versus marginal habitat.

It is important to highlight that the British marine aggregates dredging industry is committed to a mitigation measure whereby the seabed post-dredging is to be returned to / left in a similar physical condition to that present before dredging. Sediments are furthermore not dredged completely (down to bedrock), but an adequate depth of suitable material (normally at least 50cm) is to be left after cessation of dredging as a 'capping layer'. These mitigation measures (detailed in Marine Minerals Guidance 1 (MMG1) (Office of the Deputy Prime Minister (ODPM), 2002)) primarily facilitate the re-colonisation and recovery of benthic communities (Joint Nature Conservation Committee (JNCC) and Natural England, 2011). The measures should also facilitate the seabed in the Anglian dredging areas being left in / returned to a similar state to that which it currently is in, once the licences have expired. A new monitoring approach to ensure that the composition of sediments within impacted areas remains within an acceptable range is currently being implemented, based on instructions by Cooper and Koch (2013), and the MMO guidance on 'Benthic Characterisation' (MMO, 2013). Thus, in summary, once a dredger has moved on, whilst the habitat the herring may have previously used for spawning may have been dredged, there would generally still be an appropriate layer of suitable sediment remaining. Should a given licence area be changed too much with regard to seabed sediment, it is assumed that remedial measures would need to be taken by the licensee; this would also ensure that habitat preferred by spawning herring would largely remain unchanged in extent. Consequently, it is not expected for there to be any significant long-term habitat change / spawning herring habitat loss.

The herring spawning season for the Southern Bight / Downs herring population, which spawns in the English Channel and Southern Bight of the North Sea (and could spawn in the Anglian region), is understood to last from during November to January (Cefas, 2001).

5.2.1.2 Significance statements

The following PIZ-related pathways specified by Reach *et al.* (2013) are considered here:

- Direct removal of suitable sediment;
- Direct removal of eggs; and
- Alteration of habitat structure.

Direct Removal of Suitable Sediment

The direct removal of sediment suitable for herring spawning in the PIZ of the Anglian MAREA region could affect up to 7.3% of the possibly present spawning grounds (high to low confidence combined) over the course of the 15 year licence terms. Without mitigation measures, the magnitude of this would be high in a regional context. However, due to the mitigation measures listed above, as well as the limited (15-year) duration of the aggregate licences, it is considered highly unlikely that large scale habitat change would occur; however, small scale patchy habitat change cannot be discounted. Consequently, *magnitude* is at worst assessed as 'low' for this pathway. This is due to the small extent, medium-term duration and rare frequency anticipated for an event which would actually lead to habitat change due to seabed removal. With regard to *sensitivity* to habitat change of this magnitude, it is thought that herring have a medium tolerance, medium adaptability and high recoverability and consequently a medium sensitivity to such change. Coupled with a medium value/importance, a **Minor Significant** impact is assessed.

Direct Removal of Eggs

Egg removal may occur on the theoretically suitable grounds during any given spawning season. 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 proportion of the area. *Magnitude* of this is considered to be very low, due to the very low extent affected during any given spawning season, and the likely low intensity of spawning taking place across the majority of the region. Frequency is assessed as 'occasional', as the dredging of suitable habitat would have to coincide with the spawning season, and duration would be temporary. With regards to *sensitivity*, this is assessed as medium, due to a low adaptability of eggs, which once laid can not move to avoid the draghead. Tolerance is considered to be medium and recoverability high due to the large extent of spawning habitat which would be unaffected in the MAREA region during any given spawning season. Considering these magnitude and sensitivity assessments, as well as a value/importance of 'medium' for the receptor, the effects on eggs are assessed as **Not Significant**.

Alteration of Habitat Structure

The direct contact of the draghead with the seabed could lead to the physical alteration of the structure of the sediments that herring spawn on. Bathymetric changes could occur, flows could be altered, and sediments disturbed. However, it is not thought that areas affected by such changes become immediately unsuitable. Fine materials would generally be dispersed / quickly re-suspended due to the high energy conditions within the MAREA region. A radical change in sandy/gravelly sediment composition would be required to make a given patch of seabed unsuitable for spawning herring, given the range of sediment classes it appears to be able to spawn on (see Section 4.1.1). Should radical changes to the habitat structure occur, impacts could be long-term in duration. However, it is considered that such radical change would be occasional in frequency (given the mitigation measures mentioned above), and that the extent would likely amount to a small percentage of the available habitat across the region. Consequently, *magnitude* is assessed as 'medium' for this pathway. Based on the evidence provided under the 'impact commentary' regarding bathymetry and anticipated flow changes, it is considered that spawning herring have a medium tolerance, high adaptability and high recoverability to the predicted effects, and *sensitivity* is thus considered to be 'low'. Due to the 'medium' value/importance assigned to spawning herring, and the medium magnitude, an impact of '**Minor Significance**' is recorded.

Uncertainty: There is considerable uncertainty with regard to the level of herring spawning activity in the Anglian region, which could be improved by the IHLS survey being extended further inshore. Considerable variation furthermore exists in the literature as to the grain size preferred by spawning herring, although 'gravel' seems to generally be agreed upon (see

Appendix A of Reach *et al.* (2013)); hence the precautionary inclusion of the 'marginal' habitat category in this assessment. Confidence in the MAREA sediment layer was considered to be high (MES, 2013). Confidence in the other layers which contributed to a score in the Anglian region was judged to be as follows: IHLS – high; VMS data – high (though this data was judged as a low value indicator of spawning); Coull *et al.* – low (though medium indicator).

5.2.2 Contribution of Other Activities

There are several other activities taking place in the Anglian region, which potentially affect spawning herring in a similar fashion as seabed removal by the marine aggregates industry, specifically:

- Offshore renewables arrays (habitat loss and egg entrainment/mortality during installation);
- Trawl fisheries (habitat disturbance and egg mortality);
- Dredge fisheries (habitat disturbance, egg mortality, and potentially removal);
- Oil and gas pipelines (habitat loss and egg entrainment/mortality during installation);
- Telecommunication cables (habitat loss and egg entrainment/mortality during installation); and
- Dredge material disposal sites (habitat loss and egg entrainment/mortality during installation).

These activities constitute those which are considered to be the main activities which could affect spawning herring habitat. It is beyond the cope of the CIAs to take into account all possible cumulative impacts from other activities both inside and outside of the MAREA regions from national and international sources, which could have further impacts on spawning herring beyond the regional scale. Activities not considered include the operational phases of oil, gas and renewable infrastructure. It is also acknowledged that the buffered cable routes assessed above are approximations and do not capture all forms of cable protection.

Actual habitat changes would mainly be expected from the installation of windfarm foundations and the laying of cables and pipelines. As shown in Table 2, the latter account for very small percentages of potential seabed affected. By far the largest area of footprint is due to trawler fishing - 53% of the total high/medium/low confidence areas present in the Anglian MAREA region, whereas aggregates account for some 7.3%, and disposal sites for 9.2%. These footprints, as previously mentioned, are unrealistic worst case footprints, particularly with regard to temporary effects such as egg removal / disturbance, as only small percentages of the overlap areas would actually be affected by applicable activities in a given spawning season. With regard to egg mortality, demersal trawling has the potential to have a significant effect with regard to egg mortality, and thus, aggregates dredging in combination with trawler fishing is likely to have at least a minor adverse effect on egg survival. However, aggregates dredging would only be considered to make a small contribution to this effect. With regard to habitat change and habitat structure, it is not thought that cumulatively the effects of aggregates dredging and other activities would lead to a higher effect than the 'minor significant' effect already assessed for aggregates extraction, as aggregates extraction would be the main contributor in a regional context (provided previously mentioned marine aggregates industry mitigation measures are continued). Recovery of seabed would not occur for windfarms, cables and pipelines; however, the footprint of these impacts, in a regional context, is very small for potentially suitable herring spawning grounds.

Please note that the footprint of the Round 3 windfarm licensing area was disregarded for this assessment, as there is high uncertainty with regards to placement of future windfarms (excluding East Anglia ONE), and as the actual turbine footprint would only account for a very small percentage of the licence area.

5.3 Suspended Sediments

5.3.1 Impacts from Marine Aggregates Dredging

5.3.1.1 Impact commentary

Herring eggs are sensitive to plume effects. Firstly, temporary fining of seabed sediment could lead to non-adherence of eggs on suitable substrate. However, it is considered unlikely that silt sediment fractions would settle on the bed on a large scale, as currents are generally strong enough to keep these in suspension (ABPmer analysis of HR Wallingford, 2010). Secondly, during a two-hour window following release, herring eggs are sensitive to suspended sediment concentrations (SSC) exceeding 250mg/l, as this can lead to increased egg aggregation. However, eggs being affected during this period do not suffer lethal effects, but increased abnormal hatch rates and lower larvae survival occur. Beyond this two-hour window, effects of high SSC (above 250mg/l) are not thought to lead to recruitment effects (Griffin *et al.*, 2009; 2012).

The potential area affected by a sediment plume exceeding 250mg/l was not displayed in the Anglian MAREA plume study (HR Wallingford, 2010); 100mg/l was the highest SSC displayed. During dredging operations, SSCs are likely to considerably exceed 250mg/l directly below the dredger and in the immediate vicinity of the dredging operation. However, as the sediment plume disperses, these concentrations will rapidly reduce with distance. Based on the modelling presented in the Anglian MAREA, as well as that undertaken for the Humber MAREA (ABPmer, 2012), it is likely that the extent of the 250mg/l plume will be in the order of half that of the 100mg/l (mapped) plume. As such, the average extent of 250mg/l outside of the Application Areas is likely to be in the region of 100m (where dredging takes place at the edge of the area; i.e. the worst case scenario), although this is likely to be considerably less in the majority of cases.

As plumes disperse in a matter of hours (Emu, 2012), the potential spatial extent of this plume over suitable habitat within the SIZs is thought to be very small, and certainly much less than the ca. 6% of herring confidence layers which overlap with the SIZs (i.e. which would only be affected if dredging occurred over all the areas simultaneously, and along the outer edges).

5.3.1.2 Significance statement

This impact relates to the pathway 'Smothering of eggs in SIZ' defined by Reach *et al.* (2013).

Based on the evidence presented above, it is considered that the area (extent) of suitable herring habitat which could be affected by high SSC plumes would be very small over the course of a given herring spawning season. Duration would be temporary, and frequency occasional, amongst others given the likely very low to low spawning intensity taking place on the suitable habitats in MAREA region. Consequently, the *magnitude* of effect is considered to be very low. Whilst sensitivity of eggs would be high in the 2-hour window, it is low outside of this; overall a medium *sensitivity* is hence assessed (due to a medium adaptability, medium tolerance and high recoverability (as fines would rapidly disperse)). These coupled with a value/importance of 'medium' for the receptor, this leads to impacts of marine aggregates dredging being assessed as **Not Significant.**

Uncertainty: There is considerable uncertainty with regard to the level of herring spawning activity in the Anglian region, which could be improved by the IHLS survey being extended further inshore. However, confidence in the MAREA sediment layer was considered to be high (MES, 2013), thus elevating the confidence of the Area-specific assessment. Confidence in the MAREA modelling results is considered to be high.

5.3.2 Contribution of Other Activities

There are several other activities taking place in the Anglian region, which potentially affect spawning herring in a similar fashion as suspended sediment plumes released during marine aggregates dredging, specifically:

- Offshore renewables arrays (plumes during foundation dredging and piling);
- Trawl fisheries (plumes due to trawl being towed on seabed);
- Oil and gas pipelines (plumes during installation);
- Telecommunication cables (plumes during installation); and
- Dredge material disposal sites (plumes during disposal).

There could be some new cable laying in relation to East Anglia One, however, the worst case power cable footprint of this amounted to less than 0.001% of the high/medium/low confidence layers combined. Foundations for the wind farm could have an impact, however, this would be a temporary and rare impact restricted to the site only. Trawl fishing, which affects a very large percentage of the overall potential habitat area, would also be unlikely to have a significant effect due to the relatively small nature of plumes and relatively small area likely to be affected during the spawning season. Thus, it is not thought that a significant cumulative effect would arise on spawning herring due to plumes created by marine aggregates and other activities.

5.4 Fine Sand Dispersion

5.4.1 Impacts from Marine Aggregates Dredging

5.4.1.1 Impact commentary

Dredging could theoretically lead to habitat becoming too sandy in SIZs as a consequence of screening (though this is not always practised). With regard to the likelihood of significant bedforms or veneers forming outside of the immediate vicinity of the respective dredging areas which would actually lead to habitat change, it is considered highly unlikely that this would occur beyond ca. 200m of the boundary of the areas. This is because, based on the MAREA modelling studies (see Appendix B to Emu, 2012), the peak flow conditions in the MAREA region area generally high enough for fine to mediums sands would tend to get mobilised in spring and normal tidal conditions. They may not be strong enough across the whole region to mobilise very coarse sand (ca. 1.5mm) under all but spring tide conditions, and gravel larger than ca. 2mm under any normal spring tide conditions, but such coarser screened material would be expected to fall out immediately below/adjacent to the dredger, and would thus not affect the SIZs.

The deposition of sand resulting from screening could also lead to eggs being smothered by sediments, which would lead to egg mortality.

5.4.1.2 Significance statements

This impact relates to the pathway '**Fining of suitable habitat**' defined by Reach *et al.* (2013).

Fining of Suitable Habitat

Based on the evidence presented above, it is considered that the within the suitable areas of the SIZs, the area (extent) which could be affected by sand smothering or habitat change would be very small. Also the likely very low to low spawning intensity taking place on the suitable habitats in MAREA region should be considered, as well as the temporary effect of fining due to the mobility of sand fractions in the MAREA region. Frequency of fining occurring over a significant area is considered to be 'occasional'. Thus, the *magnitude* of effect is considered to be very low. It is thought that herring would be highly sensitive to large magnitude changes. However, small-scale habitat change is unlikely to detract herring from spawning in the MAREA region. Thus, *sensitivity* of spawning herring to fining of habitat is considered to be medium at worst, should the sand content of the habitat change too much over small areas of the SIZs (due to low tolerance, medium adaptability, and medium recoverability of the habitat). Coupled with the moderate value/importance assigned to herring for the purpose of this assessment, impacts are considered **Not Significant**.

Uncertainty: There is considerable uncertainty with regard to the level of herring spawning activity in the Anglian region, which could be improved by the IHLS survey being extended further inshore. However, confidence in the MAREA sediment layer was considered to be high (MES, 2013), thus elevating the confidence of the Area-specific assessment. Confidence in the MAREA modelling results is also considered to be high.

5.4.2 Contribution of other Activities

With the exception of the disposal of dredge fines, none of the other activities is considered lead to significant fine sand dispersion. Dredge material disposal sites are however only used occasionally (e.g. the closed site within aggregates area 401/2 was only utilised four times over 10 years), and licensed tonnages are generally small, thus magnitude of effect would be unlikely to be significant. Due to the potential cumulative effects of marine aggregates dredging having been assessed as not significant, and disposal sites not being considered to contribute significantly, overall, no significant cumulative effect is anticipated due to marine aggregates dredging and other activities.

5.5 Summary and Conclusions

The potential for cumulative impacts to occur on spawning herring due to aggregates dredging and several other activities in the Anglian MAREA region has been assessed. Marine aggregates extraction is generally not considered to lead to significant cumulative impacts requiring mitigation, as long as existing industry mitigation measures are continued, and given the often temporary magnitude of the effects as well as the licences being time limited. Uncertainty is recognised with regard to several aspects, most notably the herring spawning density in the Anglian region. Of the other activities taking place in the region, trawling affects by far the largest area of potentially suitable habitat. Nevertheless, overall it is not thought that, based on conservative footprint and suitable herring seabed assumptions, cumulative effects arising from all the activities combined are more than minor significant.

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Appendix J: Outer Thames Estuary Regional Cumulative Impact Assessment

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1 ASSESSMENT OF CUMULATIVE IMPACTS FROM MARINE AGGREGATE EXTRACTION ON ATLANTIC HERRING SPAWNING HABITAT IN THE OUTER THAMES ESTUARY

1.1 INTRODUCTION

Demersal spawning fish species are sensitive to the effects of activities which interact directly with the seabed. Atlantic herring are demersal spawners and have been reported as being sensitive to disturbance to spawning habitat from direct removal, or to alteration of particle size distribution (fining) of those sediments with the potential to act as spawning habitat (de Groot, 1980, 1986; Aneer, 1989; Morrison *et al*., 1991; Geffen, 2009; ICES, 2012).

Based on current perspectives and knowledge it has been suggested by the Regulatory Advisors Group (RAG) that past aggregate extraction Environmental Impact Assessments (EIAs) have not sufficiently addressed cumulative and in-combination impacts(1) in relation to Atlantic herring and sandeel spawning. As a result, the British Marine Aggregate Producers Association (BMAPA) and The Crown Estate approached MarineSpace Ltd to facilitate the delivery of a strategic protocol to address the environmental effects of marine aggregate extraction in relation to areas that have the potential to support Atlantic herring and sandeel spawning habitat. The objective was for the study to support individual applications under the Marine Works Regulations (as amended 2011) (MWR), through the creation of four regional Cumulative Impact Assessments (CIAs).

MarineSpace Ltd in conjunction with four other UK marine environmental consultancies (ABPmer, ERM, Fugro Emu and MESL), the Marine Aggregate Environmental Impact Assessment Working Group (EIA WG), have developed a methodology (Reach *et al*., 2013) to assess the environmental effect pathways and significance of effects relevant to marine aggregate licence application areas and both Atlantic herring potential spawning habitat and sandeel habitat.

This CIA includes both the cumulative and in-combination effects of marine aggregate extraction on Atlantic herring spawning habitat within the Outer Thames Estuary Marine Aggregate Regional Environmental Assessment (MAREA) region (ERM, 2010).

This report will supplement the fish ecology impact assessment carried out in the Outer Thames Estuary MAREA (ERM, 2010) and should be used as a guide for future individual licence/application area EIAs in the MAREA region.

(1) The terms cumulative impacts and in-combination impacts in this CIA have been used in the same context as in the Outer Thames Estuary Marine Aggregate Regional Environmental Assessment

1.2 METHODOLOGY

1.2.1 *General Considerations*

This section outlines the Outer Thames Estuary MAREA (MAREA) methodology which has been used to conduct the CIA. The herring habitat assessment methodology (Reach *et al*., 2013) is also described.

1.2.2 *MAREA Methodology*

The MAREA was undertaken to assess the cumulative impacts of all aggregate dredging at a regional scale, and whilst the methodology employed was aligned as far as possible to the EIA methodology set out in the EIA Directive, due to the regional scale and the cumulative impact focus of the assessment the methodology and terminologies used are not always directly comparable. It is important to note that cumulative and in-combination impacts were the primary focus of the MAREA, but potential impacts arising from individual licence areas are highlighted for consideration in site-specific impact studies. This cumulative and in-combination impact assessment has applied the MAREA methodology which is outlined below.

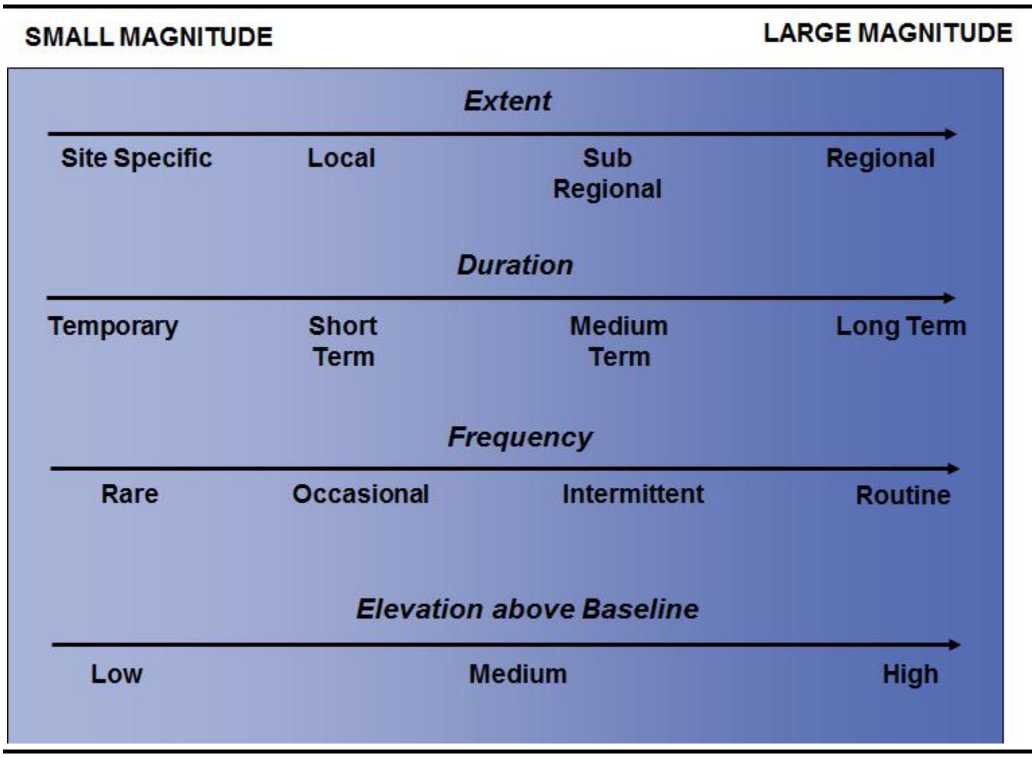
The MAREA assessment can be summarised as overlaying the extent of key physical effects which result from dredging with the extent of sensitive receptors within the Outer Thames region, including sediment removal and deposition, increased turbidity, changes to tidal current, wave and sediment transport regimes, and underwater noise. The assessment of impact significance within the MAREA applied specifically to impacts at a regional scale. An impact that had a low significance at the MAREA level may have a different level of significance for individual licence areas at the EIA stage.

For the purpose of the cumulative and in-combination impact assessment, the predicted effects from these studies are assessed in terms of three variables:

- extent (site specific, local, sub-regional, regional);
- duration (temporary, short-term, medium-term, long-term); and
- frequency (routine, intermittent, occasional, rarely).

The variables are quantified to the degree practicable. These variables collectively determine an effect's magnitude. Awarding a value to variables can be subjective in that the extent of change is difficult to define. The overall magnitude of the effect is then determined by considering a combination of elevation above baseline plus extent, duration and frequency and applying professional judgment / past experience. *Figure 1.1* shows how the components of magnitude are considered along a continuum and their individual contributions used to inform the overall prediction of effect magnitude.

Figure 1.1 Components of Magnitude



The assessment of value considers whether the receptor is rare, protected or threatened and in the case of biological receptors also considers whether the receptor provides an important ecosystem service (eg keystone species or important habitats). The sensitivity of each receptor was assessed according to three criteria, to the extent that they are applicable to the receptor in question:

- tolerance (low to high);
- adaptability (low to high); and
- recoverability (low to high).

Overall sensitivity is then determined by considering a combination of value, adaptability, tolerance and recoverability, as in *Figure 1.2*. The predicted degree of interaction between the receptor and dredging effects was also used to determine impact significance. This approach ensured that the assessment provided for a higher weighting to those receptors within the MAREA study area that will be exposed to a particular effect of dredging over much of their range, than to receptors that are only exposed to an impact in a small proportion of their range.

Figure 1.2 Receptor Value and Sensitivity

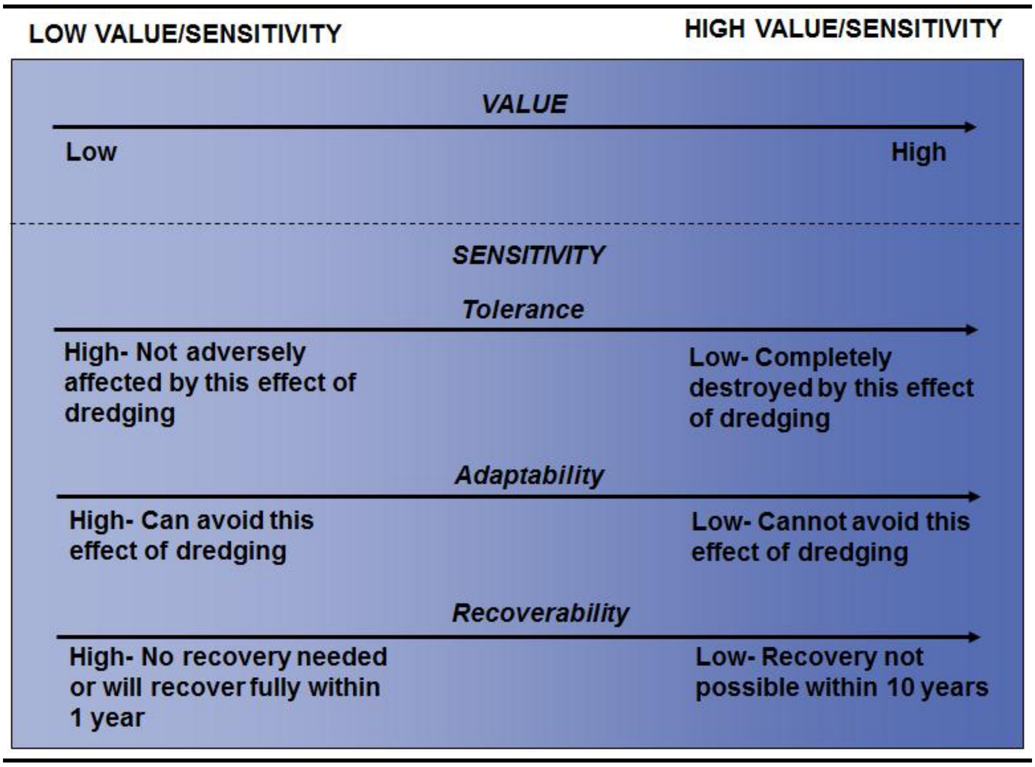
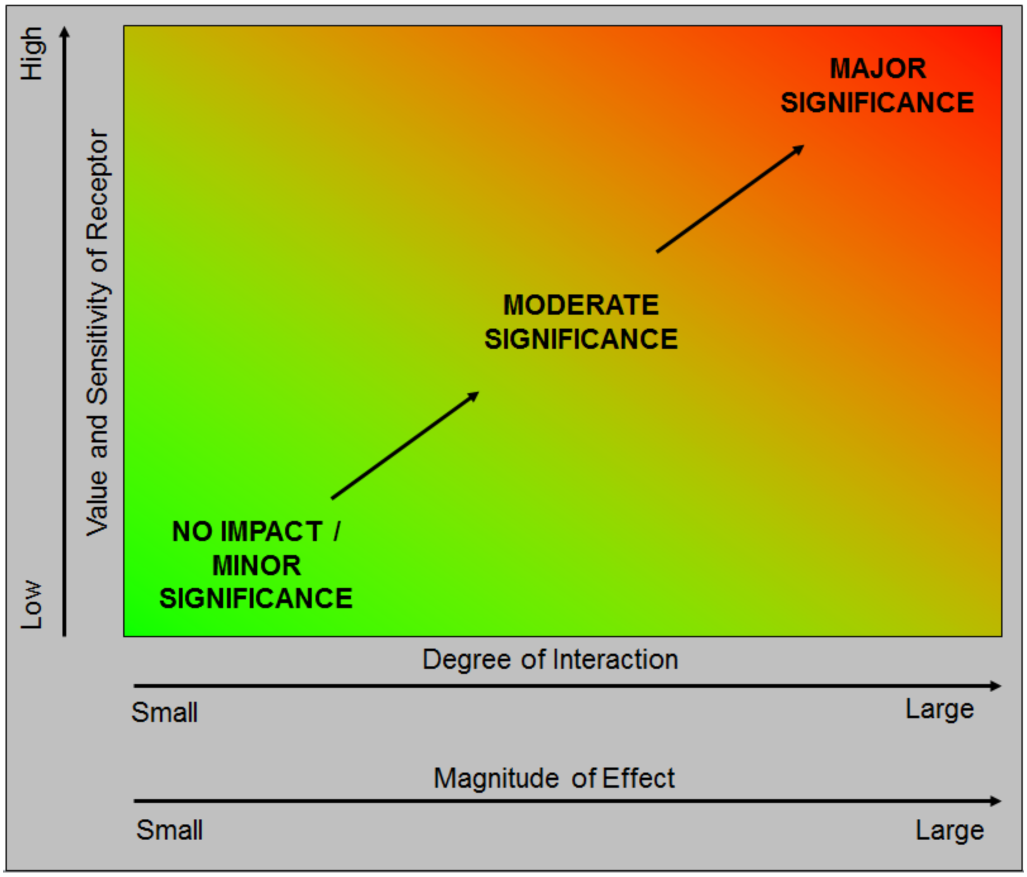


Figure 1.3 details the general relationship between the degree of interaction, effect magnitude and receptor sensitivity based on the descriptions and definitions provided in the sections above. The individual components of magnitude and sensitivity are taken into consideration together with the degree of interaction to identify the impact significance level for each effect-receptor combination.

Figure 1.3 Determination of Impact Significance



The final outputs from the cumulative assessment of all aggregate dredging at a regional scale are taken forward to the in-combination assessment which considers the interaction of aggregate extraction with other human activities in the study area to potentially create in-combination impacts. The in-combination impact assessment focuses on identifying areas where the predicted effects of dredging could interact with effects from other developments at the regional scale. This assessment uses the data presented in the EIAs for projects in other development sectors within the Outer Thames region, and the conclusions of scientific studies, to identify potential in-combination interactions.

It should be noted that the MAREA methodology adopts the rationale and metrics determined as fit-for-purpose for the MAREAs. The worst case scenario aligns with the rationale used to develop the MAREAs, ie that dredging may occur within all areas within the boundaries of licence and application areas, and that simultaneous dredging at all licence and application areas may take place.

1.2.3 *UK Aggregates Herring Habitat Assessment Methodology*

To determine the extent of available herring habitat the methodology developed by the herring aggregate working group was applied (Reach *et al*, 2013). A summary of the methodology is outlined below.

The Marine Management Organisation (MMO) and the RAG advised (at a meeting held on 01 May 2013 (MMO, 2013)) on the types of effect and effect-receptor pathways that needed to be considered as part of the requirements of the EIA Directive as transposed to the MWR. For Atlantic herring the environmental effects and effect-receptor pathways of potential impact, and how they are to be considered, are outlined below:

1. The loss of eggs can occur due to direct removal from the seabed (PIZ) and smothering (which can occur due to hopper overflow, together with sediment disturbed by the draghead and screening when dredging takes place near the boundary of the PIZ). This effect would only take place when a dredging event was coincident with a spawning event and would tend to be localised per event, infrequent but repeated over time (15 years) and space (all the licence areas).

2. Habitat conversion (including fining) can occur progressively over 15 years (and potentially prevail beyond that) as a result of: removal of all potentially suitable spawning habitat leaving a completely unsuitable substrate in place (PIZ); removal of coarser material layers leaving finer substrate in place (PIZ), settlement of fines from the plumes caused by the draghead (PIZ), settlement of fines in dredged furrows (PIZ), settlement of fines from the hopper overflow plume (PIZ and SIZ) and settlement of fines from screening (PIZ and SIZ).

It is important to note that habitat conversion through fining is not a case of changing from a favourable state for spawning to one which would not support spawning at all but from a favourable state to progressively less favourable states that may in some instances become wholly unfavourable. However, the assessment that follows initially takes a worst case approach of conversion to a wholly unfavourable status within the PIZ footprint and then makes caveats accordingly.

The MMO and RAG advised that population level effects of marine aggregate dredging on Atlantic herring are not considered to be required to be assessed under the MWR application process (MMO, 2013). In addition, entrainment of adult Atlantic herring and larvae by the dredger draghead are not considered significant in the context of an EIA.

This CIA is focussing on effects on Atlantic herring spawning habitat and eggs as opposed to population level effects. As a result this study does not consider the impacts on Atlantic herring from the same effects as assessed in the MAREA such as underwater noise. It is also necessary to slightly adapt the original MAREA assessment methodology to be fit for purpose for this assessment.

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

- Stage 1 is habitat indicator and exposure pathway mapping and screening of spatial interactions for application areas and SIZ footprints.

- Stage 2 involves a regional CIA and case study EIA.

Stage 1 applies the 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 habitat (both historic and current) 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. Licence and application areas which have overlap (exposure footprint) with receptor layers (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 CIA or subsequent EIA.

Stage 2 conducts a CIA for each of the marine aggregate strategic regions using the MAREA study area boundaries and the respective MAREA impact assessment protocols and methodologies (ERM, 2010). The rationale for this process means that the regional CIAs will act as supplements to each of the MAREAs regarding the characterisation of Atlantic herring potential spawning habitat and subsequent impact assessment. A case study EIA for a single application area per region is also conducted as part of Stage 2. These will be used to inform how the habitat assessment and CIA can be presented in any ES.

1.3 RESULTS OF SPATIAL INTERACTION SCREENING

Figure 1.4 presents the outcome of the stage 1 spatial interaction screening exercise for the Outer Thames Estuary MAREA area showing both the PIZ and SIZ for all application areas within the MAREA area.

As detailed in the methodology developed by the herring aggregate working group (Reach *et al.*, 2013), the potential Atlantic herring spawning habitat has been determined using a range of data which indicate the presence of potential Atlantic herring habitat. The data that have been used include BGS, VMS, IHLS, Coull *et al*. (1998), and fisheries data from the ESFJC. The assignment of confidence in the presence of potential Atlantic herring spawning habitat is based upon their spatial interaction across the Outer Thames Estuary MAREA area. A higher level of confidence is assigned when multiple data supporting the presence of Atlantic herring spawning habitat are available in one area. The results are presented in *Figure 1.4*. The confidence levels applied to this assessment are as follows:

- very high;
- high;
- medium; and
- low.

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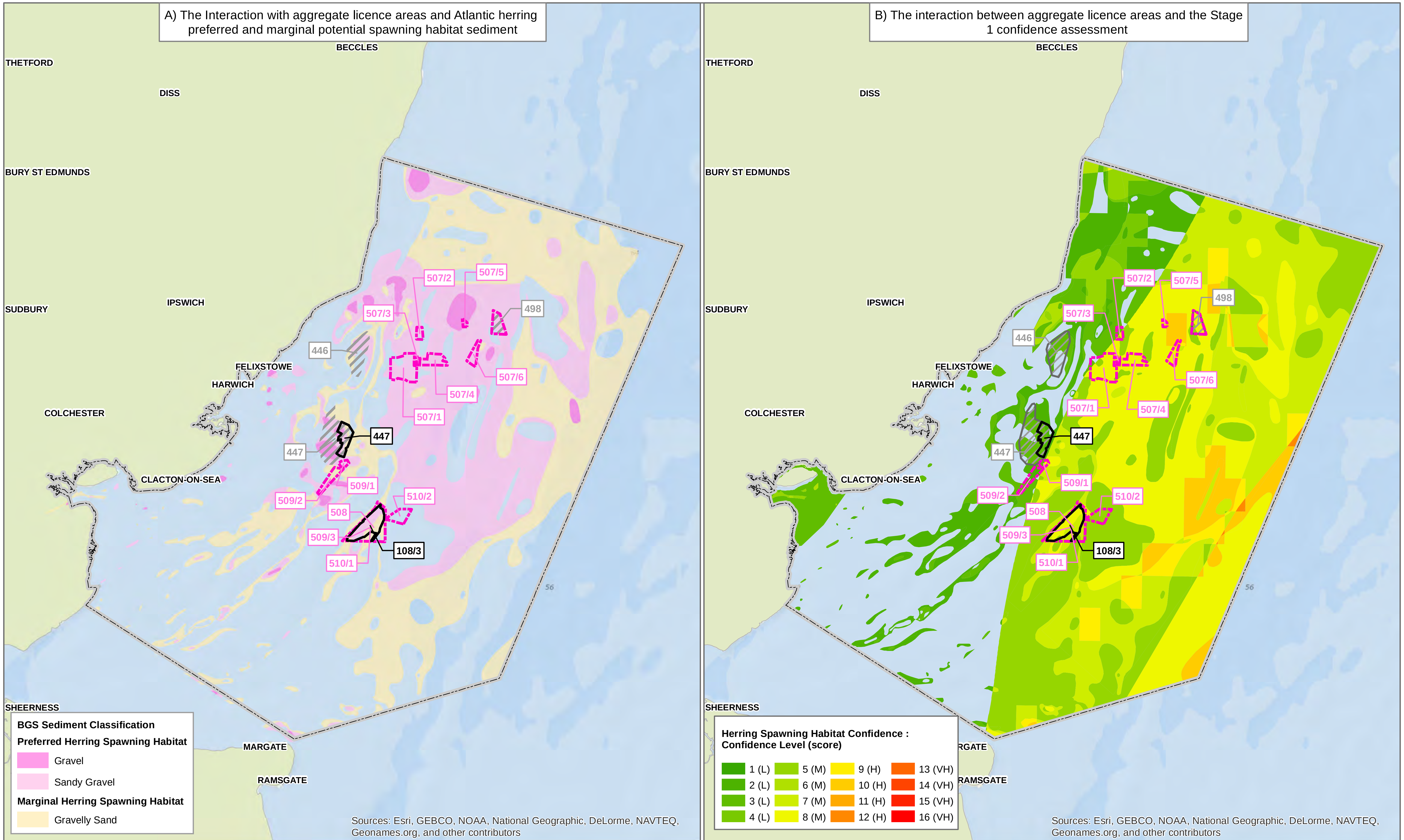


- MAREA Zone
- Current Licences
- Applications
- Options

0 5 10 15 20 25
Kilometres

N

Figure 1.4
Distribution of potential Atlantic Herring spawning habitat in the Outer Thames Estuary MAREA area

SCALE: See Scale Bar	VERSION: A01
SIZE: A3	DRAWN: AG
PROJECT: 0206159	CHECKED: KS
DATE: 12/12/2013	APPROVED: KJM

ERM

BMAPA & Crown Estates

PROJECTION: WGS 1984 UTM Zone 31N

SOURCE: The Crown Estates, BGS, CEFAS, MMO, EFJC, Esri, ALSF.

Path: C:\3_Temp\WorkingGISProjectFolders\0206159_FisheriesAssessment_AG_EB\Maps\Thames\Figure 1_4 - Distribution of Potential Herring Habitat in the Outer Thames Estuary.mxd

In accordance with the methodology developed by the EIA WG (Reach *et al.*, 2013) all aggregate licence areas (PIZ, SIZ or both) in the MAREA area were screened in to the CIA following the spatial interaction screening exercise. In the Thames region, the majority of licence areas lie within areas with medium to high confidence as potential habitat. Three licence areas (447, 446 and 509/1) overlap with areas of low confidence potential Atlantic herring spawning habitat.

1.4 CUMULATIVE IMPACT ASSESSMENT

1.4.1 Impacts from Marine Aggregate Licence Areas

General Considerations

As mentioned in *Section 1.2*, to assess the cumulative impacts of marine aggregate extraction on Atlantic herring spawning habitat it is necessary to consider the impacts in the PIZ, those related to direct removal of sediment, and the SIZ, those related to the sediment plume (Reach *et al.*, 2013).

Removal of sediment during dredging will potentially have a detrimental effect on Atlantic herring spawning through the direct removal of suitable habitat, direct removal of eggs during the spawning period, and alteration of spawning habitat.

The sediment plume generated during dredging has the potential to affect Atlantic herring spawning habitat by 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 and be used by Atlantic herring as spawning habitat will also be considered because this may impact future recruitment within the North Sea Atlantic herring population, all other factors such as fishing pressures and climate change remaining constant.

This remainder of this section is structured as follows:

- value/importance of Atlantic herring;
- impacts to Atlantic herring:
    - direct removal of eggs in the PIZ;
    - smothering of eggs in the SIZ;
- impacts from habitat conversion:
    - direct removal of suitable spawning habitat;
    - alteration of habitat structure; and
    - fining of suitable spawning habitat.
- recovery of suitable habitat and potential recolonisation.

Value/Importance of Atlantic Herring

Atlantic herring is a commercially important species; in 2009 Atlantic herring constituted the second largest catch by the European Union and was the second largest catch by UK vessels (European Union, 2012). This species is not targeted by commercial fishing fleets in the MAREA area (ERM, 2010) but the Thames is an important spawning and nursery area and successful recruitment to the adult population is vital to maintain sustainable stocks. In addition, Atlantic herring is a priority UK biodiversity action plan (BAP) species. Taking this into account Atlantic herring has been assigned a **high value**.

Impacts to Atlantic herring eggs

<u>Direct removal of eggs in PIZ</u>

The removal of eggs during dredging is assessed to be a **small magnitude** effect due to the site specific extent (ie the seabed actually dredged during a spawning event will be much smaller than the licence areas) and the temporary duration. The frequency of effect will be occasional because dredging would need to be coincident with a spawning event.

The Outer Thames MAREA area supports two spawning Atlantic herring populations; the Blackwater herring and Downs herring. Eagle bank, located in the Blackwater estuary, supports spring spawning Blackwater herring (Cefas, 1981). Downs herring spawn in the autumn/winter (Dickey-Collas, 2009) and are expected to be present in the west of the MAREA area. Atlantic herring deposit large numbers of eggs in multi-layer mats on the seabed; in one spawning event Atlantic herring have been known to spawn between 750,000 and 2,500,000 eggs per m^2 in discrete beds within a wider area of 160,000 m^2 (Stratoudakis, *et al*., 1998). Herring spawning beds are typically around small localised features rather than in extensive unbroken mats; a study by Reid *et al*. (1999) recorded size ranges of Atlantic herring spawning beds between 0.067 and 1.39 km^2. In addition, eggs typically hatch within 2 weeks (Stratoudakis, *et al*., 1998); however, Atlantic herring individuals lay eggs in the same area covering previously deposited eggs, as a result the hatching period may extend over a 4 to 5 week period.

Atlantic herring have a medium tolerance to removal of eggs because the removal of eggs during dredging will result in mortality and may have a detrimental effect on recruitment. The adaptability of Atlantic herring to this effect is low because once herring have deposited their eggs on the sediment the eggs cannot avoid the draghead. The recoverability of Atlantic herring is high because the majority of spawning habitat within the MAREA area is present outside of the aggregate licence areas (and the smaller areas within them that might be dredged during an actual spawning event) and Atlantic herring are therefore expected to deposit much greater numbers of eggs outside of the licence (and dredge) areas than within. The potential for eggs to be removed during dredging will only occur during such a 4-5 week period. Based upon the tolerance, adaptability and recoverability, the sensitivity of herring to eggs removal during dredging is **medium**.

There is no very high confidence potential spawning habitat in the Outer Thames Estuary area and, therefore, the aggregate licence areas within the MAREA area do not overlap with any very high confidence spawning habitat. There is an overlap between aggregate licence areas and 99.29 km^2 of high and medium confidence spawning habitat and 59.69 km^2 of low confidence spawning habitat. Within the MAREA boundary there is 325.98 km^2 of high confidence habitat, 796.96 km^2 of medium confidence habitat and 2968.93 km^2.of low confidence habitat. Therefore, aggregate licence areas overlap with 3.6 % of the total potential spawning habitat in the MAREA, and 14% of high and medium confidence habitat. Initially taking into account the worst case scenario presented above, the degree of interaction between dredging activity and direct removal of eggs is **medium** to **large**. However, the footprint of the dredging activity that will occur during the spawning period in the MAREA area will be a small proportion of the total PIZ area and consequently the overlap with potential herring spawning habitat will be **small**.

The impact of direct removal of eggs during dredging is of **minor** to **moderate significance** based upon the high value of Atlantic herring, the small magnitude of effect, medium sensitivity and the small degree of interaction.

Smothering of eggs in SIZ

The deposition of sediment onto the seabed as a result of dredging operations (including screening) is assessed as being a **small magnitude** effect, based on it being a localised and short-term effect that will be occasional in frequency (because dredging would need to be coincident with a spawning event), and constitutes a low level change relative to the baseline.

Atlantic herring have medium tolerance and adaptability to smothering as a result of the fine sediment plume because smothering can result in mortality of some eggs within the most affected parts of the SIZ (ie nearest to the PIZ and decreasing with distance) since the eggs are immobile once deposited and so are unable to avoid the effect. As mentioned above, herring deposit their eggs in thick mats on the seabed with between 750,000 and 2,500,000 eggs per m^2 over an area of 160,000 m^2 (Stratoudakis *et al*., 1998). Herring eggs within a fine sediment plume footprint would have low recoverability to the effects of smothering; however, the degree of recoverability will vary from low to high with distance from the PIZ boundary and therefore the overall recoverability of Atlantic herring is medium. Based upon the tolerance, adaptability and recoverability, herring eggs have **medium** sensitivity to smothering.

The SIZ of the aggregate licence areas cover 32.86% of the high and medium confidence potential Atlantic herring spawning habitat within the Outer Thames Estuary MAREA area; the low confidence spawning habitat found within the footprint of the SIZ is 2.11%. However, eggs are only present on the seabed during the spawning period in the MAREA area with each egg hatching within 2 weeks (Stratoudakis, *et al*., 1998) and eggs present in one area for a period of 4 to 5 weeks. In addition smothering effects will decrease rapidly with distance from the licence boundaries. Taking this into account the overall degree of interaction between sediment deposition and smothering of eggs is considered **small**.

Based upon the high value and medium sensitivity of Atlantic herring, the small magnitude of effect and the small degree of interaction, the overall impact on Atlantic herring from sediment deposition within the SIZ is an impact of **minor significance**.

Habitat Conversion

Direct Removal of Suitable Sediment and Alteration of Habitat Structure in the PIZ

The removal of potentially suitable spawning habitat by dredging is considered to be site-specific in extent because it will only occur within the PIZ and be short-term in duration. Without mitigation measures the complete removal of the potentially suitable spawning habitat within the cumulative PIZ footprint could be considered a high magnitude effect but because the aggregate industry is required to leave a layer of sediment at the cessation of dredging that is similar to that which existed before dredging commenced, the potentially suitable spawning habitat is unavailable at most only during the licence duration, and as the sediment composition will be similar at the cessation of dredging it will be easier for Atlantic herring to return to spawning grounds within <10 years. The effect is intermittent in frequency and a high change relative to baseline levels. As such it is assessed as being a **low - medium magnitude** effect [(1)].

Physical contact of the draghead with the seabed will result in alteration of the structure of potential herring spawning habitat within the PIZ. Extraction and deepening of suitable spawning habitat within the licence areas will reduce the total area available within the MAREA area, potentially reduce seabed flow rates and lead to some degree of fine sediment collection in the drag head track. The magnitude of effect of alteration of habitat structure is **low-medium** because the effect will be site specific and short-term in duration because

([1]) The effect of dredging considered in this assessment differs from that presented in the MAREA. The MAREA considered the effect of sediment removal while this assessment considers the effect of removal of suitable spawning habitat because it is specifically related to the impacts on Atlantic herring.

disturbed sediments will to some extent be reworked by natural sediment transport mechanisms and in the longer term aggregate licence operators are required to leave a layer of sediment at the cessation of dredging that is similar to that which existed before dredging commenced. The effect will be intermittent in frequency and represent a medium change from baseline conditions.

Atlantic herring would have a low tolerance and adaptability to the removal and alteration of all or most of the available potentially suitable spawning habitat because Atlantic herring only spawn on sediment classified by the Folk classification as gravel, sandy gravel and gravelly sand (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). Atlantic herring also require high velocity of water flow (1m/sec) (de Groot, 1979). In the context of dredging activity in the MAREA area, only a proportion of the available spawning habitat within the PIZ will be affected during dredging by removal and/or alteration habitat structure and this will not make the habitat immediately unavailable or wholly unsuitable; instead the habitat composition will alter over the 15 year licence period possibly making some areas gradually less suitable.

Atlantic herring are therefore considered to have medium tolerance and adaptability to this effect; Atlantic herring are considered to have a high recoverability because the entire PIZ will not become unavailable for spawning and they will be able to spawn on other areas of potentially suitable spawning habitat elsewhere within the MAREA area. Although the total area of suitable sediment may be reduced making it more difficult to find a suitable spawning location, should any related reduction in recruitment take place recovery is expected to recover within the medium term (<10 years) all else being equal. Taking into account the tolerance, adaptability and recoverability the overall sensitivity of Atlantic herring to removal of potentially suitable spawning habitat is **medium.**

The aggregate licence areas overlap with 3.6% of the available potential spawning habitat in the MAREA area and 14 % of the high and medium confidence potential habitat. The degree of interaction is considered to be **medium** because the calculations represent the worst case scenario of suitable habitat becoming wholly unsuitable habitat immediately. In reality the preferred and marginal habitat will alter to the extent of potentially becoming less suitable over the 15 year licence period.

Taking into account the high value, medium sensitivity, low-medium magnitude of effect and medium degree of interaction, the overall impact of direct suitable spawning habitat removal and alteration of suitable habitat is of **moderate significance**.

Fining of suitable habitat in SIZ

Any changes to sediment particle size as a result of dredging activity will be localised, short-term in duration and will represent a low level of change relative to the baseline. However, they will be 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 suitable habitat within the SIZ because they will be unable to spawn on previous spawning grounds if the sediment composition is outside the range of suitable habitat which is gravels, sandy gravels and gravelly sands (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); however, there is additional suitable habitat within the MAREA available for spawning. Atlantic herring are expected to have a medium recoverability changes in the sediment particle size because any reduced recruitment of the Atlantic herring stock is expected to recover within the medium term (<10 years). Based on the tolerance, recoverability and adaptability of Atlantic herring to fining of suitable habitat the sensitivity is considered to be **medium.**

The SIZ of the aggregate licence areas cover 32.86% of the high and medium confidence potential Atlantic herring spawning habitat within the Outer Thames Estuary MAREA area; the low confidence spawning habitat found within the footprint of the SIZ is 2.11%. It is worth noting that this represents a worst case footprint as the assessment assumes that the level of fining will be the same for the entire SIZ, whereas the degree of fining lessens as the distance from the PIZ increases. Taking this latter factor into consideration, the overall degree of interaction between fining of suitable habitat and Atlantic herring potential spawning habitat is **small**.

Taking into account the high value and medium sensitivity of Atlantic herring, small magnitude of effect and small degree of interaction between fining of sediment particle size and Atlantic herring habitat, the overall impact on Atlantic herring is assessed to be **minor significance**.

Recovery of Suitable Habitat and Potential for Re-Colonisation

During aggregate extraction spawning habitat within the PIZ may not be available for Atlantic herring at times. At the cessation of dredging the PIZ will become fully available again for spawning as all aggregate licence operators are required to leave a layer of sediment at the cessation of dredging that is similar to that which existed before dredging commenced. Leaving a layer of suitable habitat within the licence area ensures that potential spawning habitat is only affected for the duration of extraction. Population fluctuations of Atlantic herring in the North Sea over the past 50 years show that the species can re-colonise historic spawning grounds after periods of up to 25 years (Schmidt *et al.*, 2009). Therefore, the importance of operators maintaining suitable spawning habitat on cessation of dredging will be key in ensuring the spawning grounds continue to be available.

1.4.2 Contribution of Other Seabed User Activities

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

- offshore renewable arrays;
- trawl fisheries;
- dredge fisheries;
- oil and gas pipelines;
- telecommunication cables;
- power cables; and
- dredge fines disposal sites.

Figure 1.5 shows the distribution of other seabed user activity with potential herring spawning habitat in the Outer Thames Estuary as represented by the confidence assessment carried out at Stage 1 and preferred and marginal habitat (Reach *et al.*, 2013). The potential impacts of the other seabed user activities on herring spawning habitat vary according to the activity.

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 herring 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.

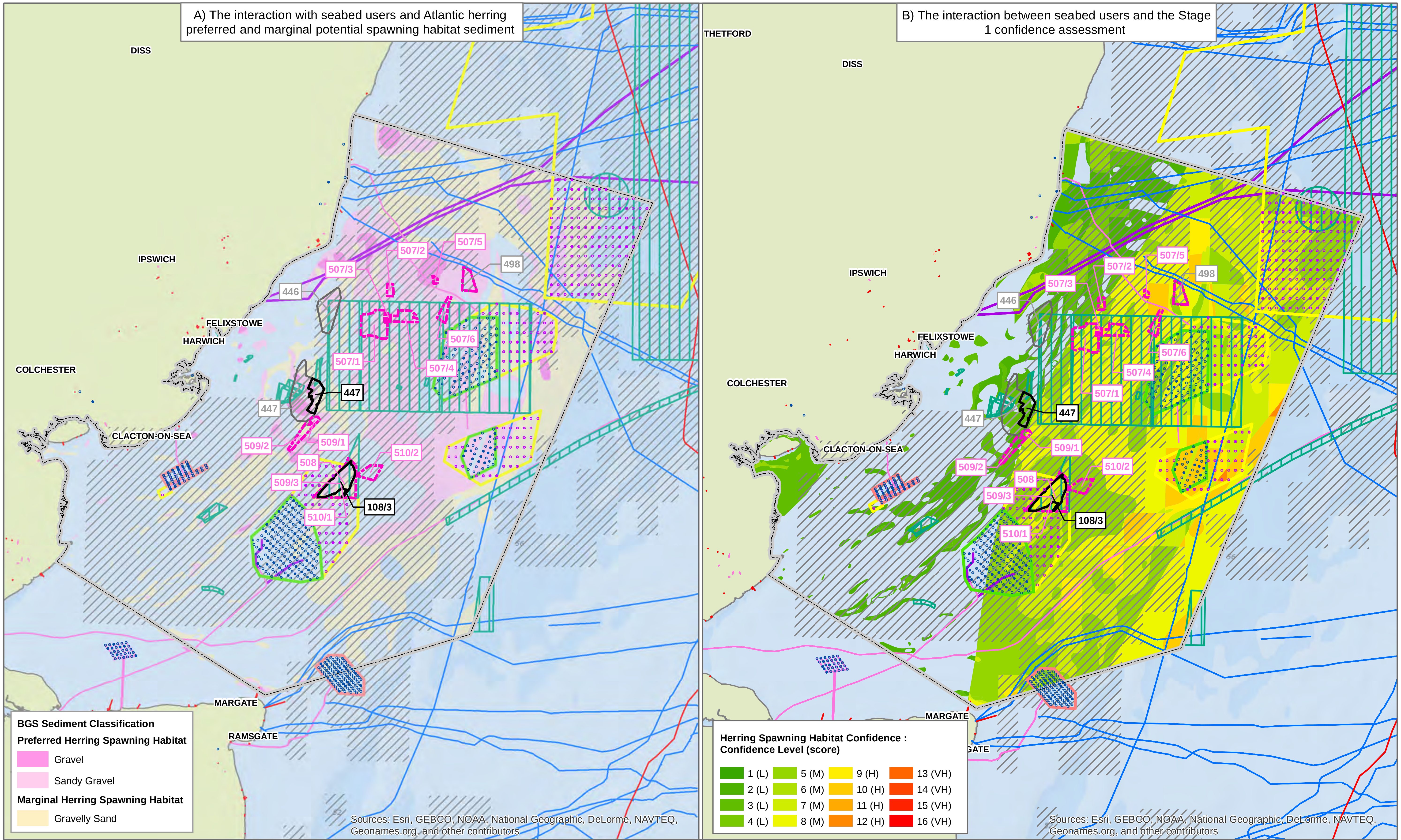
Table 1.1 quantifies the interaction between the other seabed user activities and potential spawning habitat across the MAREA study area as indicated by the confidence assessment carried out at Stage 1. The total footprint figures represent seabed user interaction with potential spawning habitat with varying confidence levels (very high, high, medium and low) as explained in the methodology, albeit each sector interacting to a varying degree via different impact pathways.

The results show that there is no interaction between seabed users and very high confidence potential Atlantic herring spawning habitat. The largest degree of interaction occurs with the medium confidence habitat and seabed users. The overlap is approximately 92% of the potential habitat in the MAREA area. High confidence potential habitat has a small interaction with seabed users (4%) and a slightly larger interaction for the low confidence areas (14%).

When compared to all other seabed user footprints, the contribution from dredging activity is considerably smaller than from the other seabed users (*Table 1.1*).

Dredging activity constitutes 3.6% of the overlap between total seabed user activity and potential spawning habitat for Atlantic herring across the MAREA area while trawl fisheries have the greatest footprint, contributing 64% of the overlap. Noting the mitigation measures employed by the dredging industry, and the fact the impacts identified will only be present for the duration of the licence, the contribution of aggregate dredging to the long term loss or continued alteration of suitable spawning habitat is negligible. The results of this in-combination assessment indicate that Atlantic herring spawning habitat within the Outer Thames Estuary MAREA is under pressure from anthropogenic activity but dredging activity only contributes to a small proportion of this.

It should be noted that seabed user activities overlap with each other and therefore the total percentages of overlap with the potential herring spawning habitat will add up to more than 100%.



PROJECTION: WGS 1984 UTM Zone 31N

- MAREA Zone
- Current Licences
- Applications
- Options
- Disposal Sites
- Pre-Planning / In-Planning & Consented
- Operational
- Under Construction
- Pipeline Footprint
- Telecommunication Cable Footprint
- Power Cable Footprint
- Proposed 'Worst Case' Power Cable Footprint for Herring
- Dermersal Trawl Fisheries Footprint
- Operating Windfarm Turbine Footprint (50m diameter)
- Potential Windfarm Turbine Footprint (70m diameter)

NOTE:
There are no dredging gear fishing activity recorded in the Thames Region

0 5 10 15 20 25
Kilometres

N

Figure 1.5
Interaction between potential Atlantic Herring spawning habitat and all seabed users in the Outer Thames Estuary MAREA area

SCALE: See Scale Bar	VERSION: A01
SIZE: A3	DRAWN: AG
PROJECT: 0206159	CHECKED: KS
DATE: 12/12/2013	APPROVED: KJM

ERM

BMAPA & Crown Estates

SOURCE: The Crown Estates, BGS, CEFAS, MMO, EFJC, Esri, ALSF.

Path: C:\3_Temp\WorkingGISProjectFolders\0206159_FisheriesAssessment_AG_EB\Maps\Thames\Figure 1_5 - Interaction between potential Atlantic Herring spawning habitat and all seabed users in the MAREA area.mxd

Table 1.1 Footprint of Seabed User Activity on Potential Herring Spawning Habitat

Seabed User Activity	Very high confidence overlap with herring spawning habitat (km²)	Very high confidence overlap with herring spawning habitat (%)	High confidence overlap with herring spawning habitat (km²)	High confidence overlap with herring spawning habitat (%)	Medium confidence overlap with herring spawning habitat (km²)	Medium confidence overlap with herring spawning habitat (%)	Low confidence overlap with herring spawning habitat (km²)	Low confidence overlap with herring spawning habitat (%)
Offshore renewables array	0.0	0.0	69.79	1.71	731.92	17.89	1.06	0.03
Trawl fishery	0.0	0.0	91.22	2.23	2284.49	55.83	560.46	13.70
Dredge Fishery	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
O&G pipelines*	0.0	0.0	0.0	0.0	0.0021	0.00005	0.00193	0.00005
Telecommunications cables*	0.0	0.0	0.00152	0.00004	0.01228	0.00030	0.00316	0.00008
Dredge fines disposal sites	0.0	0.0	14.39833	0.35188	671.47118	16.40984	34.55679	0.84452
Power cables (existing and proposed)	0.0	0.0	0.00708	0.00017	0.0368	0.00045	0.01831	0.00090
TOTAL	0.0	0.0	**175.42**	**4.29**	**3687.93**	**90.12**	**569.10**	**14.57**
Dredging activity	0.0	0.0	0.67	0.02	98.62	2.41	59.69	1.46

* assumes that entirety of cable or pipeline is surface laid and not buried, and this therefore over represents footprint for these activities.

Note: Offshore renewables array footprint calculations include operational and proposal windfarms.

1.5 SUMMARY OF IMPACTS

Table 1.2 summarises the cumulative assessment from marine aggregate extraction in the MAREA area. The MAREA assessment has designated five effects of dredging as having an impact of moderate significance; however, it is important to consider that the cumulative assessment has considered the worst case scenario for a number of the factors. As is standard industry practice dredging activity will not occur across the entire PIZ for the whole of the licence duration and as a result only a small proportion of the SIZ will be affected, resulting in a much reduced footprint of impact from that assessed here.

Table 1.2 Summary of the Significance of Cumulative Impacts from Marine Aggregate Extraction

Effect	Significance
Direct removal of eggs	Minor –Moderate
Sand deposition resulting smothering of eggs	Minor
Direct removal of suitable habitat	Moderate
Alteration of habitat structure	Moderate
Fining of suitable habitat	Minor
Recovery of suitable habitat post dredging	Not significant

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Appendix K: South Coast Regional Cumulative Impact Assessment

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HERRING AND SANDEEL HABITAT MAPPING PROJECT

South Coast MAREA Review –
Cumulative Impact Assessment of Marine Aggregate Extraction on Herring Spawning Habitat

Report Number: 13/J/1/03/2381/1533

Prepared For:

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Making Sense of the Marine Environment ™

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On behalf of:

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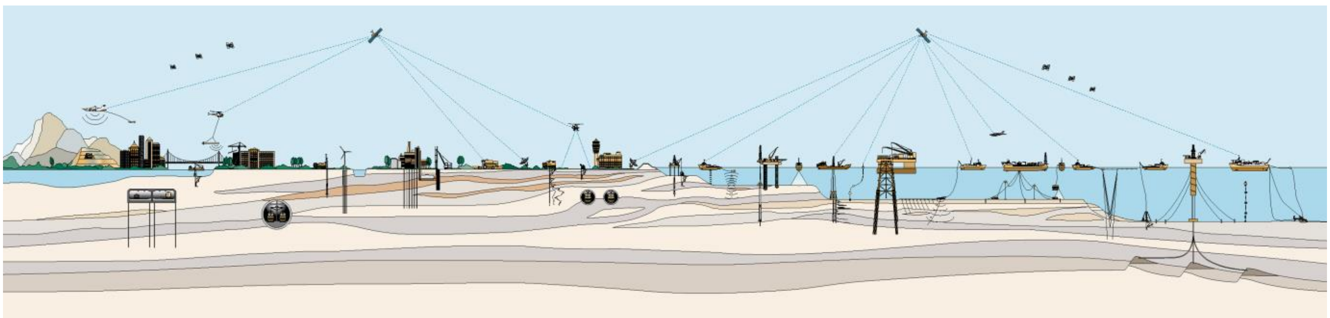
Rev	Description	Prepared	Checked	Approved	Date



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1. SOUTH COAST MAREA REGIONAL POTENTIAL HERRING SPAWNING HABITAT ASSESSMENT

Fugro EMU Limited has been commissioned to conduct a Cumulative Impact Assessment (CIA) of the South Coast Marine Aggregates Regional Environmental Assessment (MAREA) region in order to assess the significance of effects arising from marine aggregate extraction on potential herring spawning habitat.

All current marine aggregate extraction areas and application areas within the South Coast MAREA region are included in this assessment. Other seabed users that have the potential to interact with potential herring spawning habitat are identified and aggregate extraction is contextualised with these seabed users. This information is used to assess the impact significance of aggregate extraction within the South Coast MAREA region accounting for other seabed users, and based upon the sensitivity and magnitude of the potential effects on herring spawning grounds.

This assessment encompasses three main steps:

1. The identification of current marine aggregate extraction areas and application areas in the South Coast MAREA region, with reference to potential herring spawning habitat;

2. The identification of other seabed users whose activities may interact with potential herring spawning habitat, and the contextualisation of aggregate extraction with the cumulative impact assessment; and

3. An assessment of the impact significance of aggregate extraction in the South Coast MAREA region accounting for other seabed users, and based upon receptor sensitivity and magnitude of effects.

The South Coast MAREA region is not noted for its importance to Atlantic herring *Clupea harengus*, however the neighbouring eastern English Channel is an important spawning area to the Southern Bight herring stock (Mills *et al*., 2003) and there is the potential for this stock to spawn within the South Coast MAREA region. Herring are assessed specifically here as they are:

Potential areas of herring spawning habitat have been identified within the South Coast MAREA region based upon the presence of appropriate sediment type, historic spawning areas, presence of larvae and Vessel Monitoring System (VMS) data of fishing vessels potentially targeting herring (see Reach *et al*. (2013) for full methods). The data used in this assessment have been sourced from the EIA Working Group consortium as part of the wider herring and sandeel assessments currently being undertaken to support the aggregates industry in licence renewals.

The South Coast MAREA region currently contains a total of 14 marine aggregate extraction licence areas and nine licence application areas. A map of the South Coast MAREA region licence and application areas is shown in Figure 1.1.

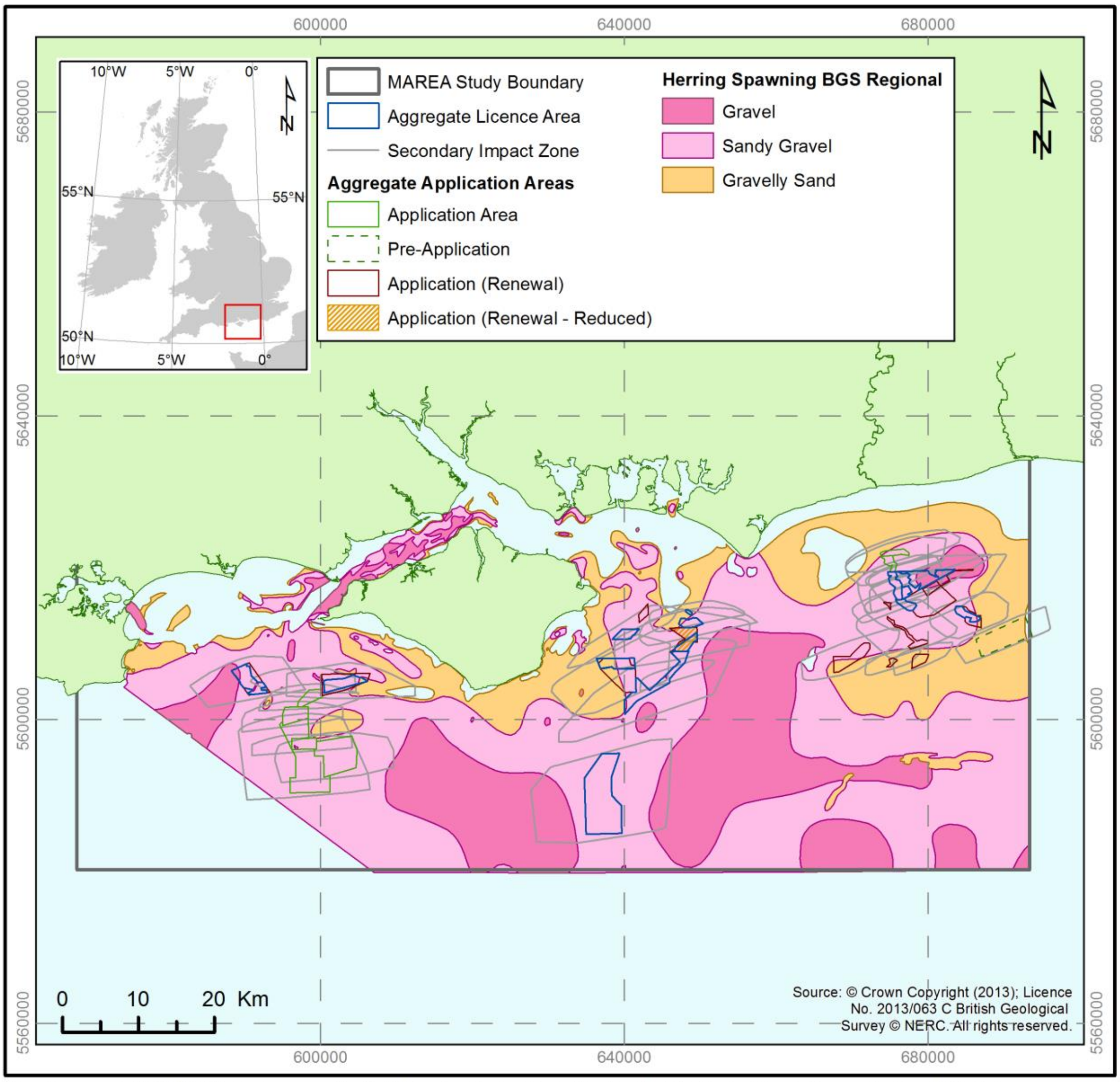

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Figure 1.1 Current and proposed aggregate extraction areas in the South Coast MAREA region.

2. ASSESSMENT METHODOLOGY

2.1 Screening

The initial screening exercise and the data utilised for this purpose have been agreed and defined in the method statement produced by the EIA Working Group and referenced as Reach *et al*. (2013).

The method depends upon screening spatial interactions between the licence area and the potential herring spawning habitat based on the Folk classification (Folk, 1954) (Gravel and sandy Gravel: preferred potential herring spawning habitat, gravelly Sand: marginal potential herring spawning habitat – see Section 3.2) and involves four steps.

- STEP 1 – Determination of the extent of the Atlantic herring populations;
- STEP 2 – Determination of suitable habitat for Atlantic herring spawning at an international/national sea/basin scale;
- STEP 3 – Determination of the potential habitat for Atlantic herring spawning in a regional context; and
- STEP 4 – Compilation of a regional broadscale habitat characterisation layers basemap.

The data utilised in the habitat assessment have been sourced from the EIA Working Group consortium, as part of the herring and sandeel spawning assessment currently being undertaken to support the aggregates industry in licence renewals. Data sourced included:

- Substrate Folk classification sourced from British Geological Survey (BGS);
- Licence and application area boundaries (Reach *et al*., (2013) method assumes that the boundary of the licence and application areas are representative of the primary impact zone (PIZ);
- Secondary Impact Zone (SIZ), footprints taken from the modelled outputs of the South Coast MAREA;
- Spawning grounds sourced from Coull *et al.* (1998);
- Atlantic herring fishing fleet AIS and VMS data (2006-2012); and
- International herring larvae survey (IHLS) data (2002-2011).

2.2 Confidence assessment

As detailed in the supporting confidence assessment (MESL, 2013), each of the data layers was first processed to extract the part of the layer that indicated each of the herring spawning habitat, for example the relevant substrate or gear type.

As all data were required in the same format to inform the combined confidence assessment, any layers not in polygon format were converted, namely the IHLS point dataset. In the first instance, all IHLS data from 2002 to 2011 were combined and then all sample locations that were limited to three or fewer interactions of sampling were removed, in case these did not target the spawning season. A nearest neighbour interpolation was then performed on the dataset, which served to assign abundance values to the areas between sample points. Contours were automatically assigned to the resulting raster dataset before undergoing conversion to polygons. All analysis was undertaken using ArcGIS 9.3.

Each dataset was then assigned a confidence level, based upon the confidence in the data itself (e.g. the age, methodology used for collection etc) as well as its reliability to indicate herring spawning habitat (each of equal weighting). By combining the different indicator layers together, the individual scores from each layer were combined (ultimately from 1 to 16) for any given location. Scores used throughout this report are classified as follows for ease of presentation:

- Confidence of 1-4 is categorised as ‘low’ confidence;
- Confidence of 5-8 as ‘moderate’ confidence;
- Confidence 9-12 as ‘high’ confidence; and
- Confidence 13-16 as very high confidence.

See Reach *et al*. (2013) and MESL (2013) for a full account of the confidence methodology.

2.3 Assessment methodology

The cumulative assessment methods utilised in this report follow those presented in the South Coast MAREA (EMU, 2012). The methods have been slightly adjusted where appropriate to suit the current assessment objectives, and to reflect the fact that only one receptor is being assessed in the case of herring spawning habitats. The methodology is summarised below.

Central to the assessment of impacts is the conceptual ‘source-pathway-receptor’ model, which has been identified by the EIA Working Group and agreed with the Marine Management Organisation (MMO) and the Regulatory Advice Group (RAG) for the impacts of aggregate extraction on herring spawning habitat. The model is effective at identifying potential impacts on the receiving environment and sensitive receptors resulting from the proposed extraction activities. It allows for a more transparent approach to conducting the assessment process by guiding assessors through the linkages between the source of the effects and the routes through the environment to potentially sensitive receptors.

The term ‘source’ describes the origin of the potential effect (e.g. the effects of aggregate extraction and plume dispersion, such as the draghead moving across the seabed) and the term ‘pathway’ as the means (e.g. deposition of sediment via the water column to the seabed, sediment transport processes and ingestion) by which the effect interacts with the receiving 'receptor' (e.g. benthic organisms, habitats, fisheries or maritime archaeology) (Figure 2.1).

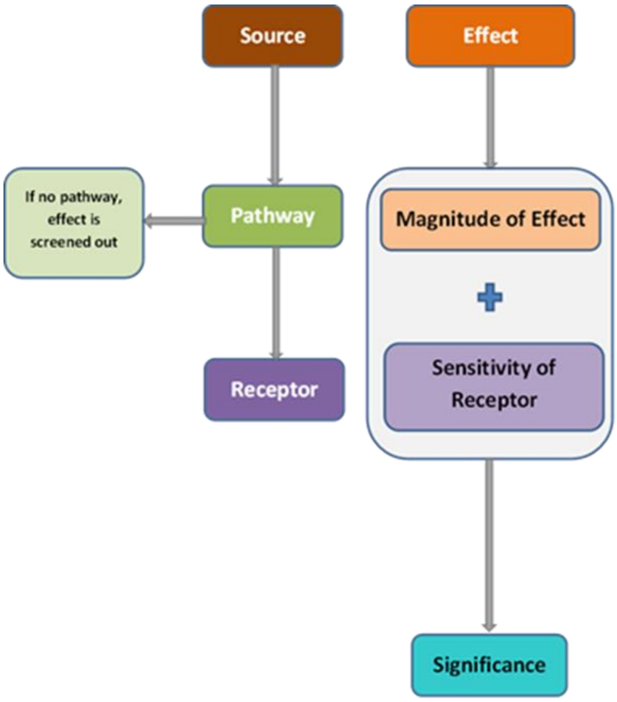

Figure 2.1 Conceptual 'source-pathway-receptor' impact assessment model

2.3.1 Determining magnitude of effect

In accordance with the South Coast MAREA (EMU, 2012), the potential magnitude of effect is assessed with reference to three variables: duration, frequency and extent, as shown in Table 2.1.

Table 2.1 Characteristics of magnitude of effect

Characteristic of magnitude of effect	Definitions
Duration	The temporal extent that the effect is noticeable against background variability. This can be temporary, short term, medium term or long term: • Temporary: Effects only occur during active dredging, are one off or last only a few hours or days after cessation of dredging; • Short-term: Effects are no longer observed after up to 1 year following cessation of dredging; • Medium-term: Effects that last between 1 and 10 years following cessation of dredging; or • Long-term: Effects that persist for >10 years following cessation of dredging. **Longer duration of effect ultimately results in higher overall magnitude.**

Characteristic of magnitude of effect	Definitions
Frequency	How often the effect occurs. This can be routine, intermittent, occasional, or rare: • Routine: Effect occurs during all normal dredging operations (95-100%); • Intermittently: Effect occurs regularly but not all the time during dredging operations (25-95%); • Occasionally: Effect only occurs during a small proportion (<25%) of routine dredging operations; or • Rarely: Effect only occurs very rarely as an unplanned event during dredging operations (e.g. emergency load dumping, oil spills). **Higher frequency of effect ultimately results in higher overall magnitude.**
Extent	The geographic area of influence where the effect is noticeable against background variability. Extent is defined through the following characteristics: • Primary impact zone: Effects that only occur where dredging occurs or is predicted to occur; • Localised: Extend beyond the immediate footprint of dredging but do not affect the receptor at a regional scale. Effects extending up to one tidal excursion beyond the licence area e.g. the SIZ • Sub-regional: Confined to an area associated with a group of licence areas that are distinct. Effects extending beyond the licence boundary (typically >10 km); and • Regional: Effects occurring across the entire South Coast MAREA region but do not extend outside it. **Greater spatial extent of effect ultimately results in higher overall magnitude.**

The characteristics of magnitude of effect are combined to provide an overall level of magnitude of effect as ‘very low’, ‘low’, ‘medium’ or ‘high’. Determination of the overall magnitude of an effect incorporates a degree of subjectivity, and quantifiable data are supported by expert judgement using previous experience of the aggregates sector, the region and consideration of elevation above baseline conditions, as outlined in MAREA approaches such as EMU (2012) and ERM (2010).

2.3.2 Sensitivity of receptor

The determination of receptor sensitivity adopts a similar approach to that for magnitude of potential effects. The sensitivity of a receptor is characterised by the following factors: adaptability, tolerance and recoverability as defined in Table 2.2. An understanding of the baseline conditions is critical to making an informed decision on sensitivity.

A further consideration in sensitivity of receptor and ultimately in determining overall significance of an impact is that of value. Value is an integral part of sensitivity and includes consideration of importance (e.g. level of conservation status and keystone species), rarity (e.g. how much of it exists relative to the potential area impacted) and worth (e.g. it’s socioeconomic, cultural and amenity value).

The exact determination of the level of sensitivity of each receptor will vary according to the receptor in question and as such, will be defined on a receptor by receptor basis using industry best practice, previous studies undertaken by the aggregate industry (e.g. EMU, 2012; ERM, 2010) and expert judgement. The overall sensitivity of the receptor is assessed as being ‘low’, ‘medium’ or ‘high’.

Table 2.2 Characteristics of sensitivity of receptor

Characteristic of sensitivity of receptor	Definitions
Adaptability	This refers to how well a receptor can avoid or adapt to an effect: • Low: Receptor unable to avoid or adapt; • Medium: Receptor has some ability to avoid or adapt e.g. by moving to other suitable areas; or • High: Receptor can completely avoid or adapt to this effect with no detectable changes. **Higher adaptability of a receptor ultimately results in lower overall sensitivity.**
Tolerance	This refers to the receptor's tolerance to the physical change: • Low: Receptor unable to tolerate effect resulting in permanent change in its abundance or quality; • Medium: Receptor has some ability to tolerate this effect but a detectable change will occur; or • High: Receptor unaffected or positively affected. **Higher tolerance of a receptor ultimately results in lower overall sensitivity.**
Recoverability	Recoverability refers to the receptors ability to recover given exposure to an effect, and has a temporal element to its characteristics (this temporal element is receptor dependent): • Low: Receptor recovers over the long term (typically >10 years); • Medium: Receptor partially recovers and/or recovers over the short term to medium term (typically 1-10 years); or • High: Receptor recovers fully, typically within weeks to 1 year. **Higher recoverability of a receptor ultimately results in lower overall sensitivity.**

2.3.3 Assigning significance of impacts

Following the assessment of the magnitude of potential effects and the receptor sensitivity for each impact pathway overall impact significance is assigned according to the classifications shown in Table 2.3.

Table 2.3 Determination of overall significance of impact

<table>
<tr><td colspan="2"></td><th colspan="4">Overall Magnitude of Effect</th></tr>
<tr><th rowspan="4">Overall Sensitivity of Receptor</th><td></td><td>Very low</td><td>Low</td><td>Medium</td><td>High</td></tr>
<tr><td>High</td><td>Minor significance</td><td>Moderate significance</td><td>Major significance</td><td>Major significance</td></tr>
<tr><td>Medium</td><td>Not significant</td><td>Minor significance</td><td>Moderate significance</td><td>Major significance</td></tr>
<tr><td>Low</td><td>Not significant</td><td>Not significant</td><td>Minor significance</td><td>Moderate significance</td></tr>
</table>

The significance of impact (see Table 2.4) is therefore determined using the best available information from a range of sources including consultation, literature reviews, empirical evidence, numerical modelling and historical data analysis, in informing the magnitude of effect, sensitivity of receptor and overall impact significance. Where data gaps exist, informed scientific interpretation and expert judgement are used to present a transparent assessment of impact significance.

The determination of significance of an impact is presented in a significance statement. This provides a categorisation of an impact as being either 'not significant', or of 'minor', 'moderate' or 'major significance'.

Table 2.4 Descriptors for overall impact significance

• *Not significant:* An impact that, after assessment, was found not to be significant in the context of the objectives.
• *Minor significance:* Where an effect will be experienced, but the effect magnitude is sufficiently small (with or without mitigation) and well within accepted standards, and/or the receptor is of low sensitivity.
• *Moderate significance:* Moderate significance impacts may cover a broad range, although the emphasis remains on demonstrating that the impact has been reduced to a level that is as low as reasonably practical. This does not mean reducing to 'minor' but managing 'moderate' ones effectively and efficiently.
• *Major significance:* Where an acceptable limit or standard may be exceeded or large magnitude effects occur and highly valued/sensitive resources/receptors are affected.

2.3.4 Other considerations

Alongside magnitude of effects and sensitivity of receptors, there are some additional considerations that may be taken into account when assigning significance of impact. These may include the following, dependent on receptor and impact type:

- Reversibility of an impact. Whether the effect can be reversed i.e. conditions can be returned to that of the baseline prior to the effect occurring;
- Severity of an effect and resultant impact (e.g. the intensity of the physical change);
- Ecosystem interactions (e.g. the links between impacts on receptors having an indirect impact on other linked receptors). This also includes consideration that there are intrinsic links between various human, biological and physical receptors; and
- Certainty of impact. This considers whether an impact is likely to occur given the predictions outlined. For the purposes of this assessment this has been integrated with the confidence assessments undertaken on the data layers (see Section 2.2).

2.4 Cumulative impact assessment

Step 4b as defined in the Reach *et al*. (2013) looks at a cumulative impact assessment to allow the characterisation of the seabed footprint of relevant seabed activities. The methodology has been developed to enable an assessment of the cumulative two dimensional footprints of seabed user activities that interact with the characterisation base map.

The methodology adopts the rationale and metrics determined as fit-for-purpose for the South Coast MAREA (EMU, 2012). It is assumed that the boundary of the application and licence areas are representative of the potential PIZ i.e. active dredging may occur anywhere within this boundary during the licence term. The SIZs used in the assessment here have been modelled from the South Coast MAREA. The cumulative assessment considers the footprint of all appropriate seabed users at the South Coast MAREA regional scale. This allows for the footprint of marine aggregate operations to be ranked with other seabed user groups and the values can be related to the potential habitat extents from the characterisation base-maps.

The seabed user activities likely to interact with Atlantic herring potential spawning habitat at a regional scale have been identified as:

- Marine aggregate licence areas;
- Offshore renewable arrays;
- Trawl fisheries;
- Dredge fisheries;
- Disposal sites; and
- Cables and pipelines.

3. HERRING HABITAT CHARACTERISATION AND SCREENING

3.1 STEP 1 – Screening to determine the extent of the Atlantic herring populations

There are four known breeding populations of Atlantic herring in the North Sea and English Channel; the Orkney/Shetland, Buchan, central North Sea and southern North Sea populations (Figure 3.1). The South Coast MAREA region overlies a small area of seabed where the southern North Sea Atlantic herring population are known to spawn. The Orkney/Shetland, Buchan and central North Sea populations have been screened out of further assessments as these populations clearly do not spawn in the vicinity of the South Coast MAREA region.

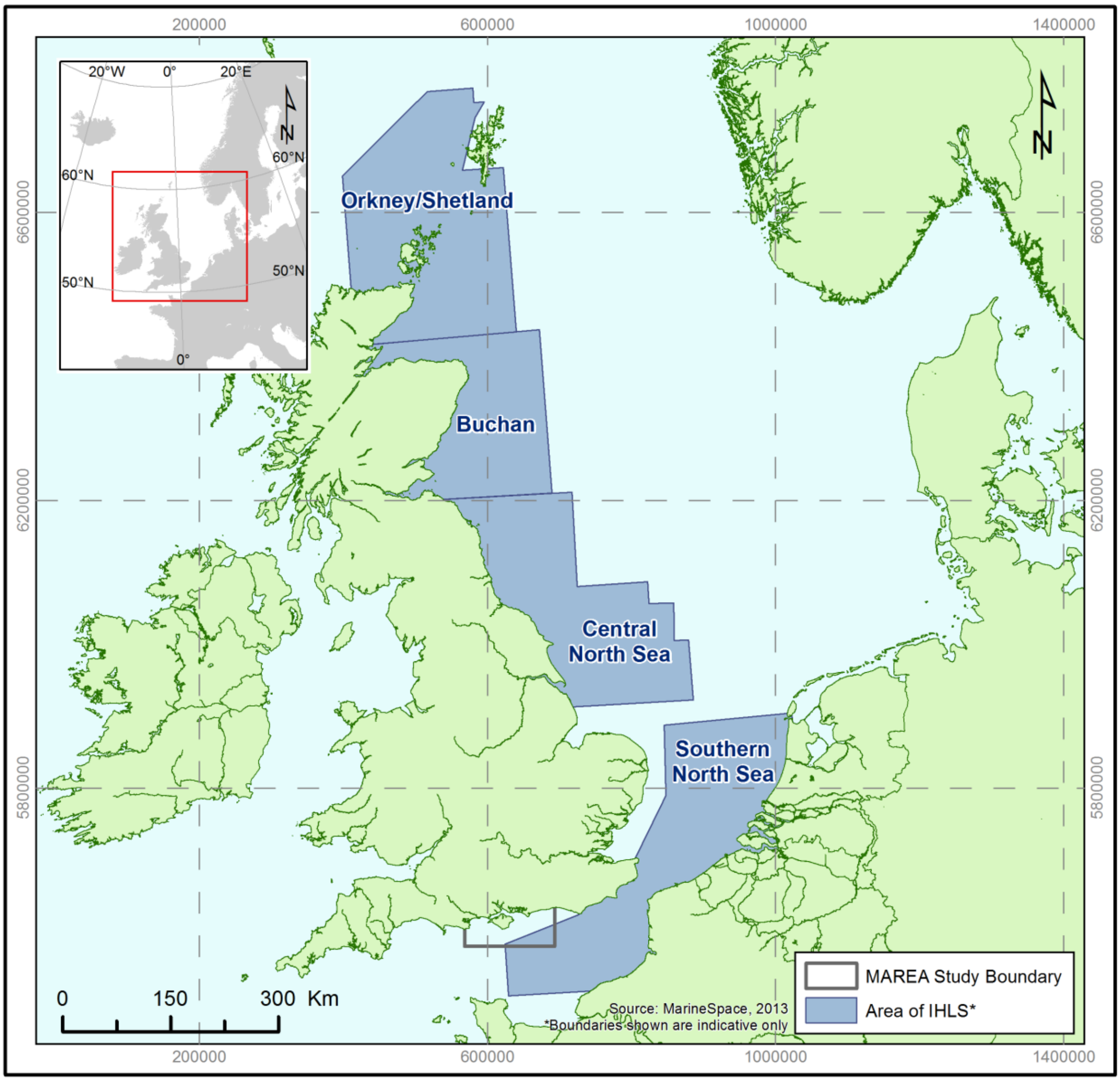

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Figure 3.1 Areas of the International Herring Larvae Survey (IHLS): Showing Orkney/Shetland, Buchan, Central North Sea and Southern North Sea herring spawning grounds in relation to the South Coast MAREA region (modified from: The Herring Network, 2006)

3.2 STEP 2 – Determining suitable habitat for Atlantic herring spawning at an international/national sea/basin scale

The sediment divisions, based on the Folk Classification (Folk, 1954), considered in this assessment having the potential to support Atlantic herring spawning are:

- sandy Gravel - sG; and
- Gravel - G.

These are considered to be preferred potential herring spawning habitats. Also considered is:

- gravelly Sand – gS.

Gravelly Sand is considered to be a marginal potential spawning habitat. These sediments proposed by Reach *et al* (2013), were agreed with the MMO and RAG (MMO, 2013).

The total extent of potential herring spawning habitat in the central and southern North Sea including the English Channel has been derived from the BGS 1:250,000 scale seabed sediment maps. A total area of 35,168 km^2 of seabed is considered to be suitable as potential herring spawning habitat, this is comprised of 17,046 km^2 of preferred potential spawning habitat (Gravel and sandy Gravel) and 18,122 km^2 of marginal potential spawning habitat (gravelly Sand) (Figure 3.2).

3.3 STEP 3 – Determining the potential habitat for Atlantic herring spawning in a regional context.

The South Coast MAREA region has been used as the regional boundary for this assessment. A total area of 4,031 km^2 of seabed is considered to be suitable as potential herring spawning habitat, comprising approximately 3,201 km^2 of preferred potential spawning habitat (Gravel and sandy Gravel) and approximately 831 km^2 of marginal habitat (gravelly Sand) (Figure 3.3). The potential herring spawning habitats within the South Coast MAREA region comprises 11.5% of the total available habitat at the international/national sea scale (preferred and marginal) (Table 3.1).

Table 3.1 Total area of potential herring spawning habitat at the national and regional scale

Scale	Herring spawning habitat	Area (km^2)	% of total potential spawning habitat
National	Preferred	17,046	48.5%
	Marginal	18,122	51.5%
Regional (South Coast MAREA region)	Preferred	3,201	9.1%
	Marginal	831	2.4%

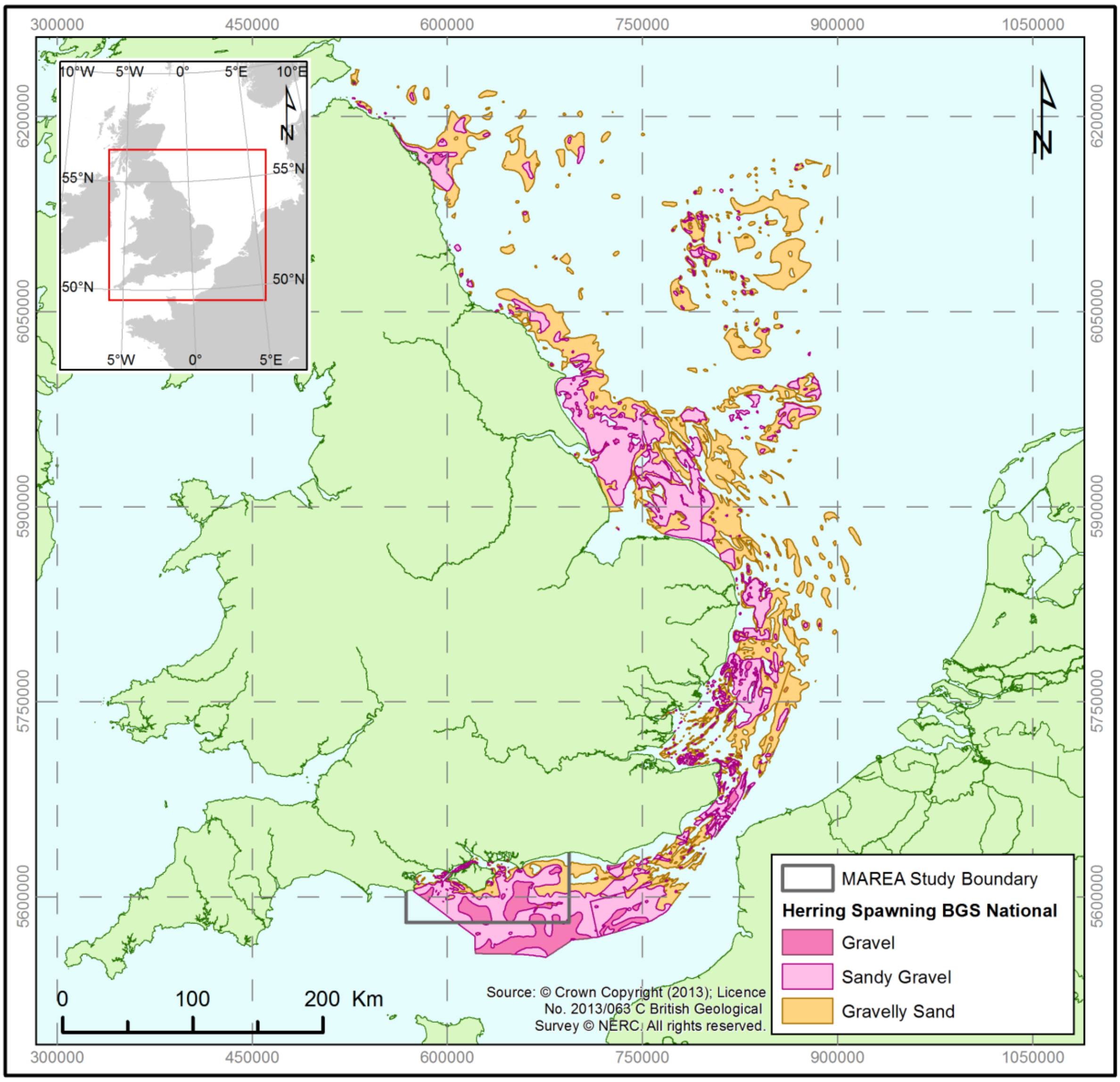

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Figure 3.2 Seascale and Regional (South Coast MAREA region) boundary areas used to define the national and regional areas of potential herring spawning habitat (Gravel or sandy Gravel = preferred habitat, gravelly Sand = marginal habitat)

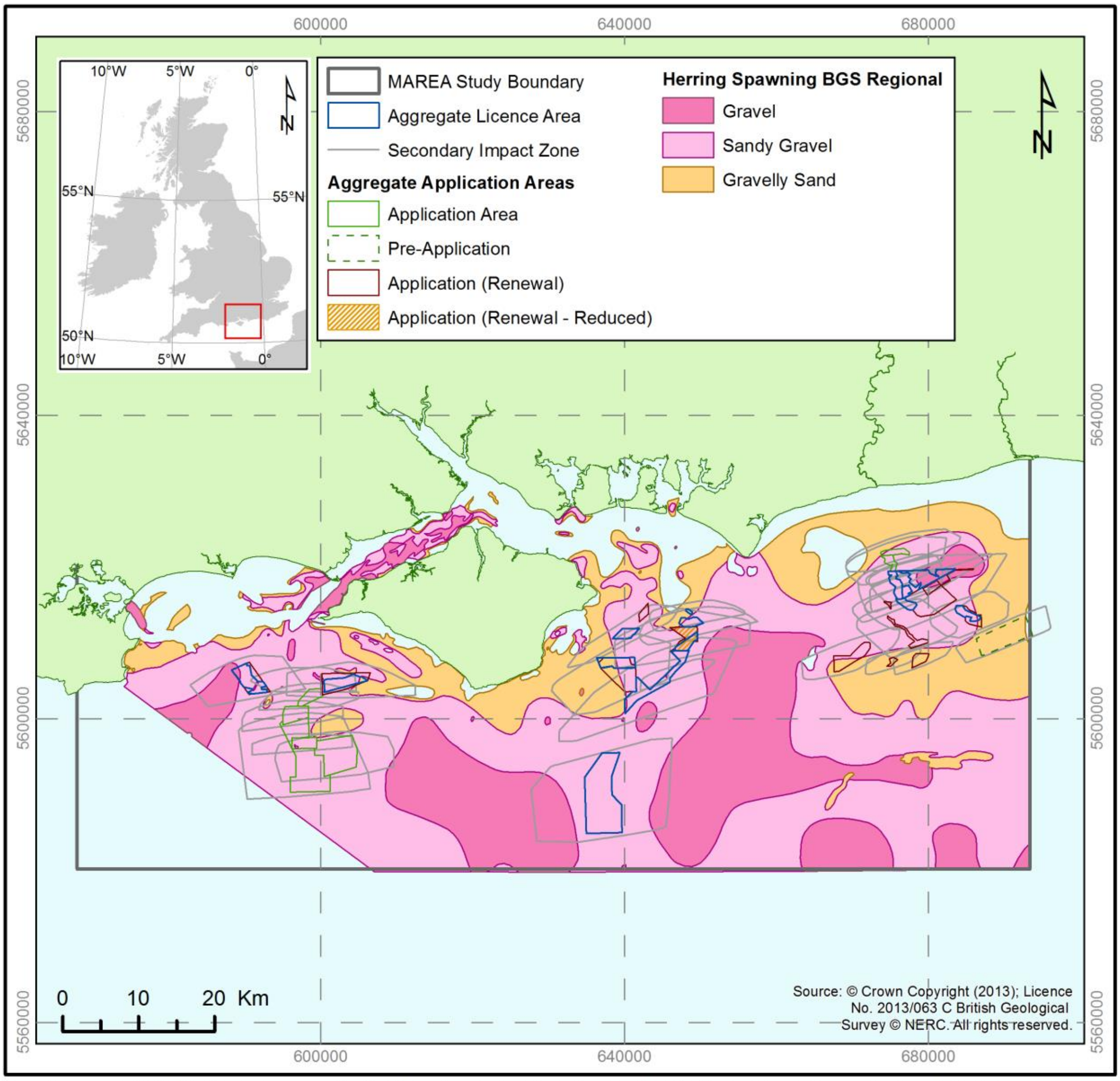

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Figure 3.3 Potential spawning habitat for Atlantic herring within the South Coast MAREA region (Gravel or sandy Gravel = preferred habitat, gravelly Sand = marginal habitat)

3.4 STEP 4 – Regional broadscale habitat characterisation layers basemap

3.4.1 Regional Assessment boundary

This regional assessment is synonymous with the ‘cumulative’ assessments undertaken in the South Coast MAREA region, and considers all aggregate extraction areas. See Figure 3.3 for the potential spawning habitat for Atlantic herring within the South Coast MAREA region.

3.4.2 Coull *et al.* (1998) layer

The next data layer incorporates the use of the Coull *et al*. (1998) spawning maps for Atlantic herring, which considered both the known location of larvae and the relationship with suitable benthic habitat (Reach *et al.,* 2013). No overlap with the spawning map occurs with the South Coast MAREA region. Spawning grounds occur to the southeast of the region (Figure 3.4). However the Coull *et al.* (1998) data layer is considered to be of low confidence because of the age of the data and the lack of detail on what underlying data was used to construct the spawning maps.

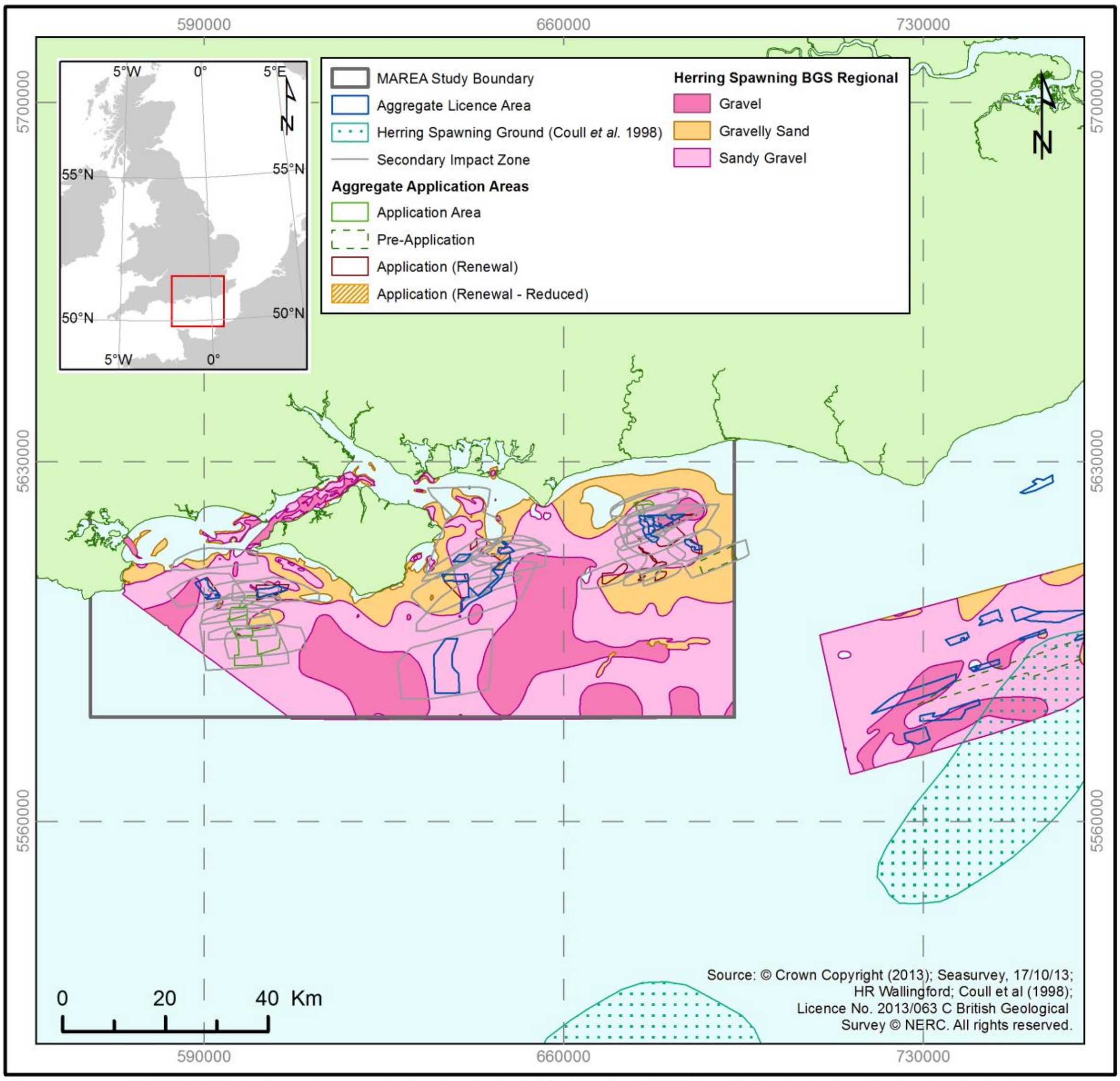

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Figure 3.4 Potential herring spawning grounds in the vicinity of the South Coast MAREA from Coull *et al.* (1998).

3.4.3 Regional Atlantic herring fishing fleet VMS data

To further ascertain the presence of potential herring spawning grounds within the South Coast MAREA region, VMS data of the commercial fishing fleet are presented below (Figure 3.5). There are limitations to this data layer as only commercial fishing vessels >15 m length are required to use VMS. Further, commercial fishing vessels using pelagic gears able to catch herring may not be targeting this species and could be targeting another species entirely e.g. mackerel. Therefore these data are not truly representative of the distribution of Atlantic herring and the confidence in the data will reflect this fact.

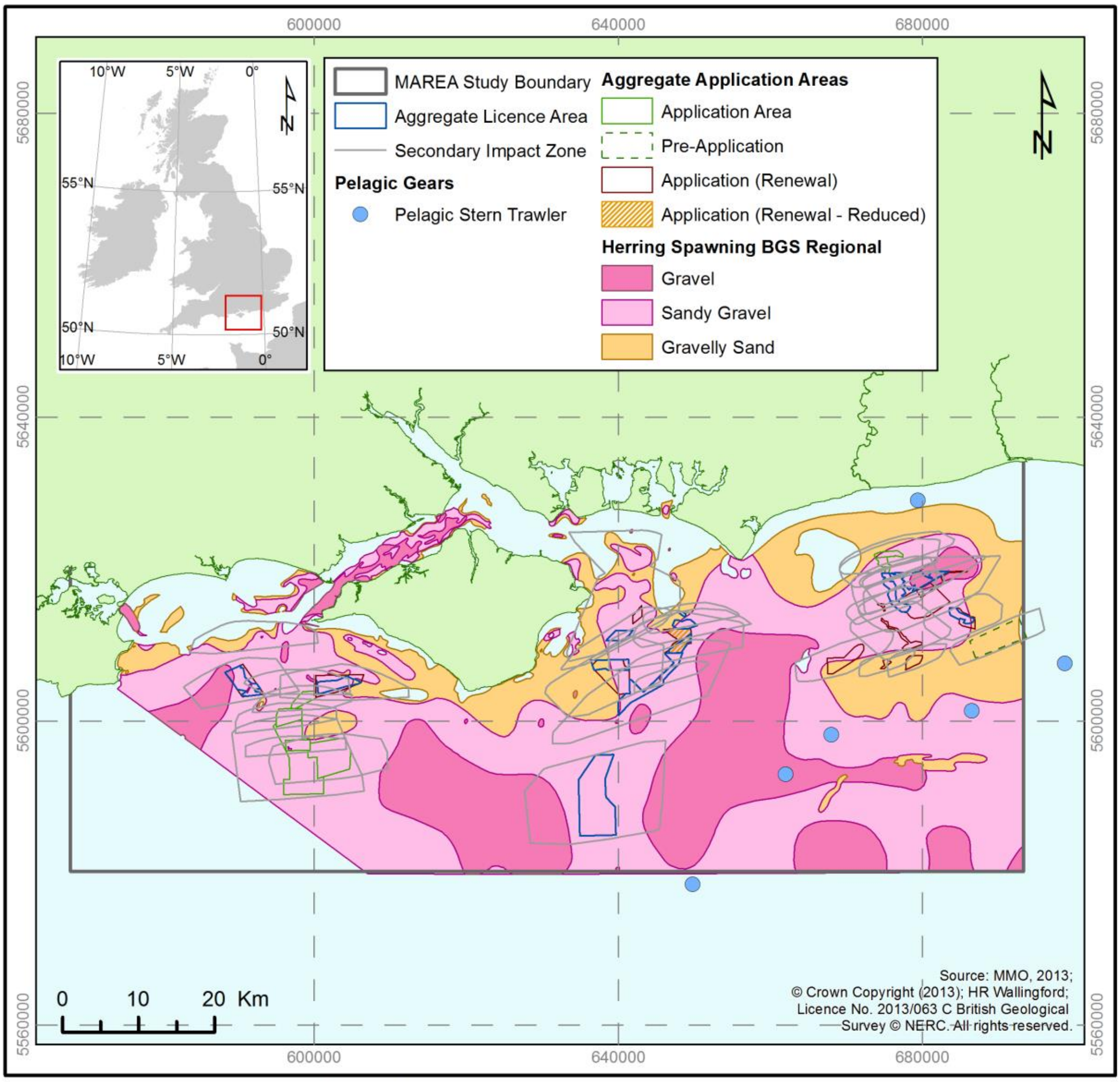

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Figure 3.5 VMS data showing the pelagic stern trawl fleet in the vicinity of the South Coast MAREA region (Gravel or sandy Gravel = preferred habitat, gravelly Sand = marginal habitat)

3.4.4 International Herring Larvae Survey data.

The International Herring Larvae Surveys (IHLS) (ICES, 2013) are carried out between September and end of January in the northwestern, central, and southern North Sea and eastern English Channel, following the spawning areas of Atlantic herring. The surveys aim to provide quantitative estimates of herring larval abundance, thus targeting the very young stages of freshly hatched herring in the vicinity of the spawning areas. Herring larvae were recorded to the south and east of the South Coast MAREA region. No larvae were recorded in close proximity to marine aggregate application and licence areas. Further, no IHLS survey occurred to the west of the Isle of Wight as this area has not been used historically by herring as a spawning ground, despite the presence of suitable sediments found there. There is a small area of overlap with the aggregate licence and pre-application areas in the east of the South Coast MAREA region. The interpolated IHLS larvae data overlap at a concentration of 51-200 larvae per m^3. However, the prime spawning grounds are located further to the southeast, outside of the South Coast MAREA region (Figure 3.6).

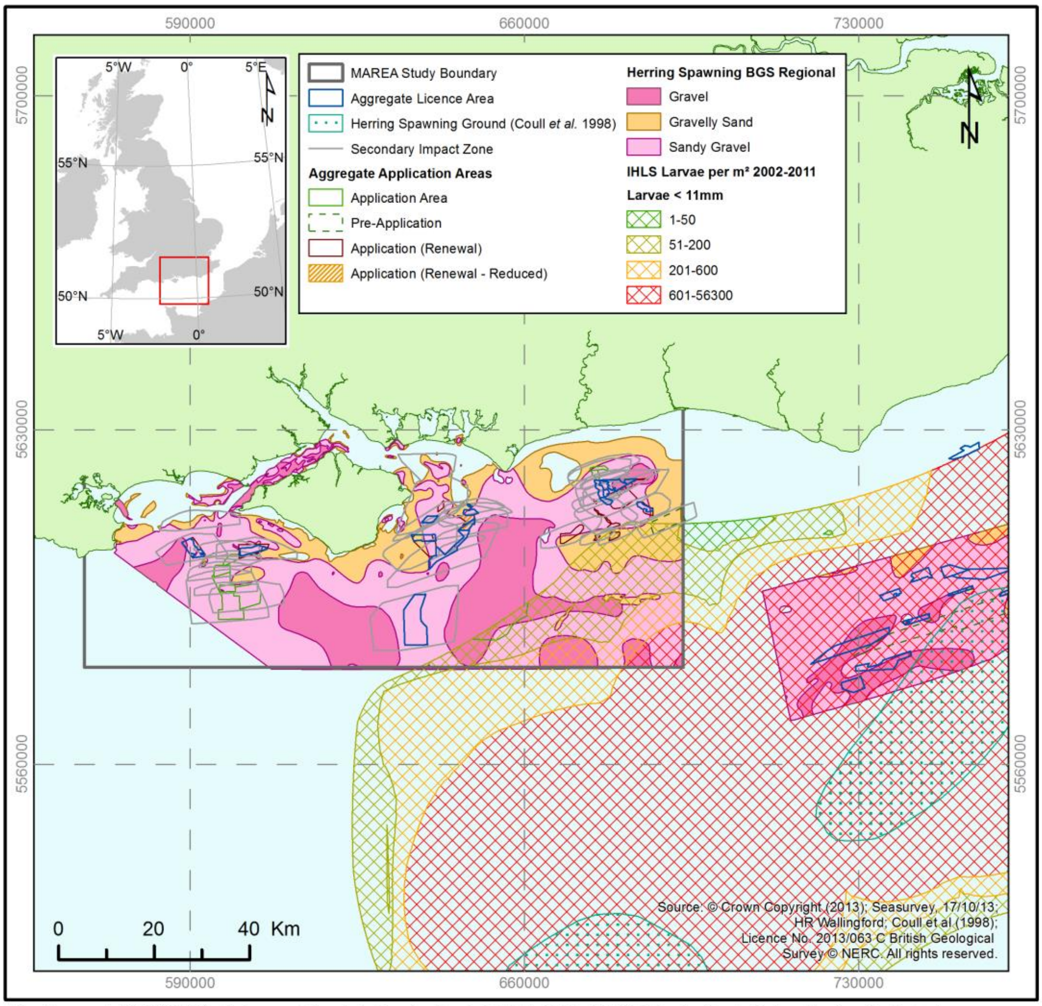

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Figure 3.6 IHLS survey data showing larvae of <11 mm in the vicinity of the South Coast MAREA region

3.4.5 Regional Screening

Current marine aggregate extraction areas and application areas in the South Coast MAREA region are shown with reference to potential herring spawning areas (Figure 3.7), derived using the methods presented in Reach *et al*. (2013) and the associated confidence assessment (MESL, 2013). These have been plotted in conjunction with the 'worst case scenario' SIZ provided to the EIA Working Group. Localities where the greatest number of data layers overlap one another results in a higher confidence that herring may spawn there.

The southeast of the South Coast MAREA region is assessed as being of high confidence; the remaining areas of the South Coast MAREA region are assessed as being of low to medium confidence. The area of high confidence is based on the IHLS data for which there is high confidence, overlaid on the Coull *et al*. (1998) spawning maps, VMS data and the availability of potential habitat for herring spawning (for which there is low to moderate confidence). Low to medium confidence in the data exists for much of the inshore South Coast MAREA region because the BGS data may over-represent the potential herring spawning grounds, but this is either the only data that exists for this area or there is overlap with the VMS data layer for which the confidence is also low.

It should be noted that the presence of the IHLS data layer has not been made to automatically force the combined confidence assessment to high as the data layer has been interpolated from point data. Whilst the IHLS dataset conforms to repeated grid sampling at fixed locations, these are far apart (~20 km). Note that the data layer is not based on any relative abundance scores, as low abundance can be equally as significant as high levels (Cefas, pers, comm.); therefore it shows only presence/absence of early stage herring larvae (less than 11 mm in length) and so is indicative of close proximity to spawning grounds.

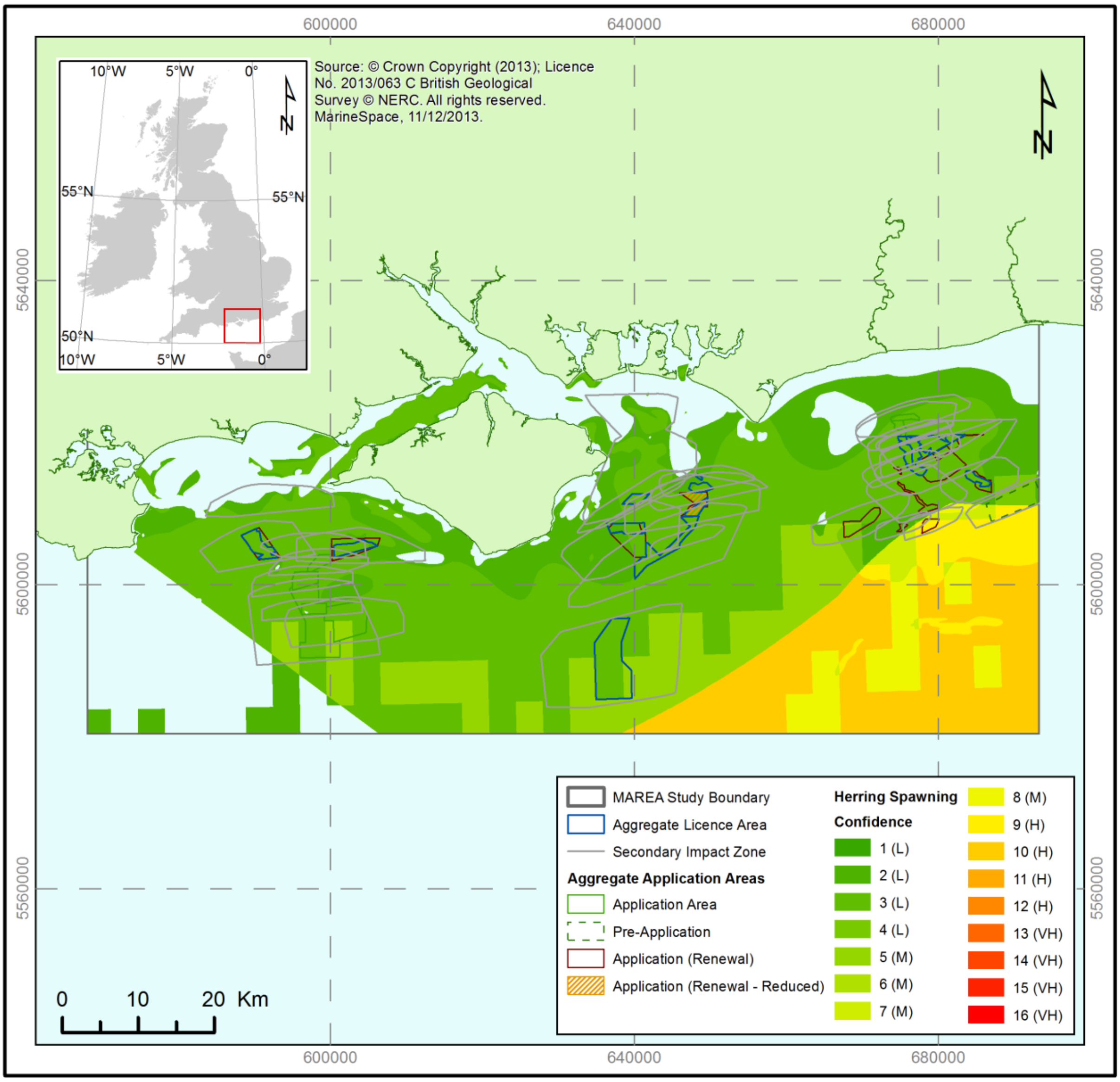

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Figure 3.7 Confidence assessment of the data layers used in the herring assessment for the South Coast MAREA region.

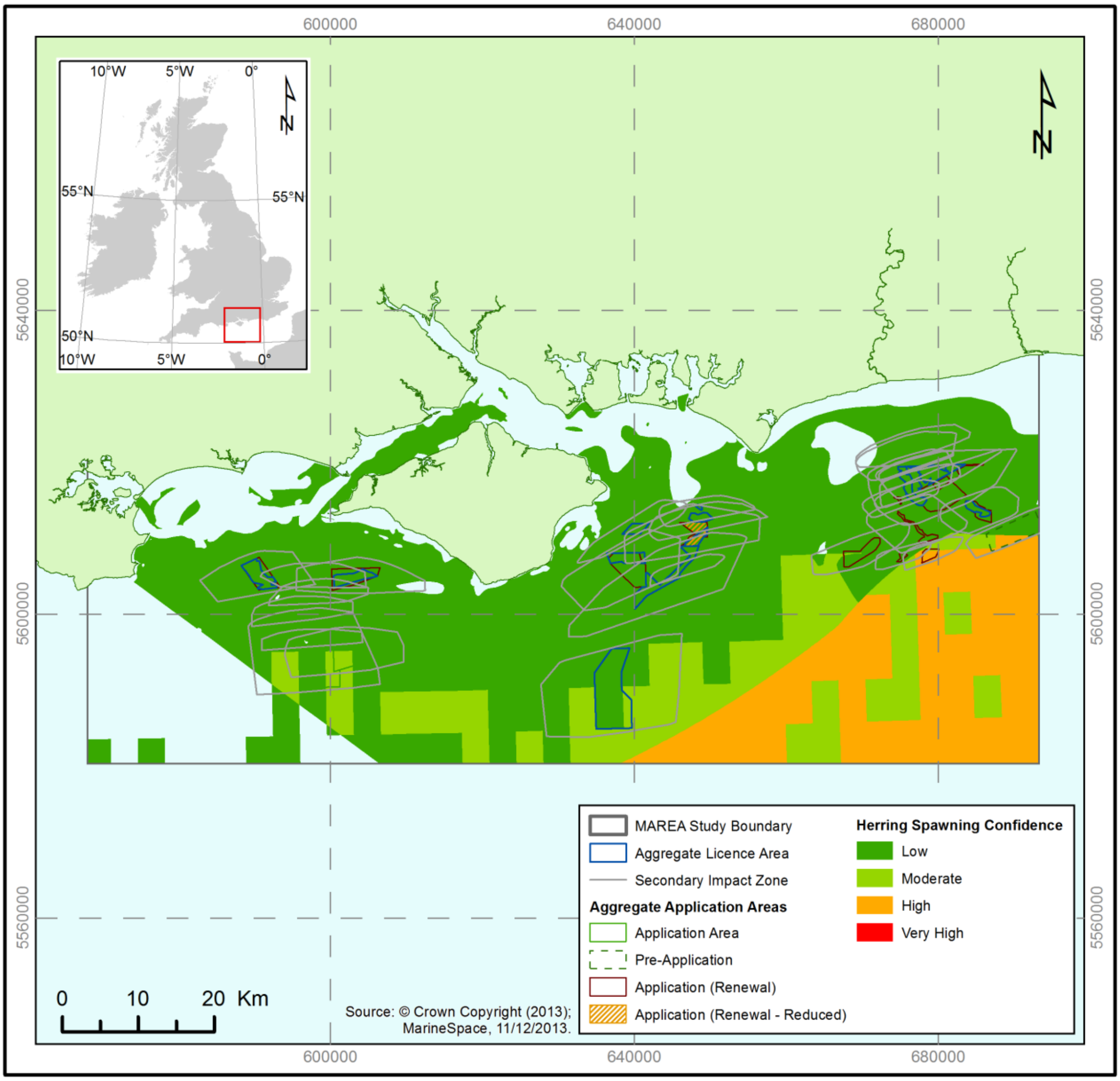

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Figure 3.8 Grouped confidence assessment of the data layers used in the herring assessment for the South Coast MAREA region.

3.4.6 Assessment of the south coast herring spawning habitat

The percentage overlap between the current and proposed aggregate extraction areas and potential herring spawning habitat, as shown in Figure 3.7, has been calculated as shown in Table 3.2.

There is a generally low to medium confidence in the South Coast MAREA region, where overlap with aggregate areas occurs, as being able to support herring spawning. However, an area of high confidence exists to the southeast of the South Coast MAREA region as a result of the presence of IHLS data.

Table 3.2 indicates the regional footprint of aggregate activity in the South Coast MAREA region, and identifies the interaction overlap between dredging and potential herring spawning areas. It can be seen that the combined current and proposed aggregate area extraction overlap of herring spawning habitat in the South Coast MAREA region is 8.43%, although the majority is made up by low to medium confidence areas, where spawning is less likely to take place. No very high confidence spawning areas occur within the South Coast MAREA region.

Table 3.2 Regional footprint of marine extraction areas (current and proposed) overlapping with potential herring spawning habitat in the South Coast MAREA region.

Percentage of very high confidence spawning habitat overlapped by cumulative aggregate footprint	Percentage of high confidence spawning habitat overlapped by cumulative aggregate footprint	Percentage of moderate confidence spawning habitat overlapped by cumulative aggregate footprint	Percentage of low confidence spawning habitat overlapped by cumulative aggregate footprint
0.00%	0.28%	0.70%	7.45%

In addition, the South Coast MAREA region contains seabed sediments which are potentially suitable for herring to spawn, with approximately 79.4% classed as preferred potential habitat (Gravel and sandy Gravel) and 20.6% marginal potential habitat (gravelly Sand) of the region. Therefore, the entire seabed within the South Coast MAREA region is identified as potential spawning habitat for herring. The area of potential spawning habitat may be overestimated due to the varying percentage of muds within the sediment divisions (refer to Folk (1954) and Reach *et al.* (2013)). Sediments beyond the extent of the South Coast MAREA region are also comprised of potentially suitable habitat for herring spawning (Figure 3.2).

Broad scale herring sensitivity maps (Coull *et al*., 1998) reveal no herring spawning or nursery areas directly located within the South Coast MAREA region. The nearest spawning grounds are located approximately 80 km to the southeast of the closest aggregate area (Application Area 499) where a relatively large spawning ground occurs.

Much of the fishing activity recorded between 2006 and 2012 by the MMO is shown to be pelagic stern trawlers located to the southeast of the South Coast MAREA region. These vessels are fishing over potentially suitable habitat for herring spawning; however, there is no guarantee that these vessels are targeting herring. Commercial fishing vessels <15 m are not required to carry VMS and so are not included in this assessment. As such, vessels targeting herring may be under-represented herein. No commercial fishing gears likely to be targeting herring were recorded close to marine aggregate sites, and those that did occur within the region may not have been targeting herring. However, based on the level of suitable habitat within and around the region, herring are screened into the assessment as they are known to alter the areas in which they spawn intermittently (Schmidt *et al*., 2009).

Herring larvae were recorded to the southeast of the South Coast MAREA region. The interpolated IHLS data revealed overlap with aggregate licence and application areas, with larvae numbers of 51-200 larvae per m^3 recorded (Figure 3.6).

Much of the South Coast MAREA region is considered to be suitable as potential spawning habitat for herring. The areas of highest confidence of potential herring spawning habitat within the South Coast MAREA region overlap with the aggregates sites in the southeast of the South Coast MAREA region (Licence Area 122-1/123 and Application Area 499) but extend further offshore to the south and east of the South Coast MAREA region. The potential herring spawning grounds within the region, when contextualised within a national setting, are considered to be low. Grounds to the southeast of the region are considered to be the prime spawning grounds for herring within the English Channel (Coull *et al*., 1998).

There is no overlap with the aggregate areas and the Coull *et al*. (1998) spawning areas data layer (Section 3.4.2), hence, the combined data layers give a **low** level of confidence that the South Coast MAREA contains potential spawning habitat for herring. Although there is medium confidence for some areas of the South Coast MAREA region, these are outside of the PIZs of the aggregate areas. It is considered unlikely that herring currently spawn within the region in significant numbers; however the potential for the region to be used by herring as a spawning ground in the future cannot be ruled out.

4. IMPACT ASSESSMENT OF SOUTH COAST REGION

This assessment of likely effects of dredging on potential Atlantic herring spawning habitat specifically considers the effect-receptor pathways, as defined in the herring method statement (Reach *et al*, 2013) and listed below. The environmental effects and effect-receptor pathways of potential impact on Atlantic herring potential spawning habitat from marine aggregate dredging are associated with both the PIZ (i.e. the licence area boundary where active dredging may occur) and SIZ (i.e. the extent of the plume either modelled from the South Coast MAREA or indicative of a precautionary halo which has been tidally adjusted). The environmental effects for both the PIZ and SIZ are defined below:

The PIZ:

- 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 SIZ:

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

It has been agreed that the potential effects of sediment plumes on herring larvae, the entrainment of larvae and adults and any effects relating to adult populations outside of those listed above are not to be considered in the context of this report (MMO, 2013).

In addition, this section provides an assessment of the cumulative impacts of dredging within the South Coast MAREA region on potential herring spawning habitat. Section 4.2 provides an assessment of the overlap of all industries within the South Coast MAREA region with potential herring spawning habitat, fulfilling Step 3 in the methodology (Reach *et al*., 2013).

4.1 STEP 4a – Regional Impact Assessment

4.1.1 Direct removal of suitable sediment in the PIZ

Removal of the seabed will result in the direct removal of potential herring spawning habitat. The effect of direct habitat removal through dredging activities within the South Coast MAREA region is regarded as having a **medium magnitude** due to the medium term duration, routine frequency and extent limited to the PIZ.

The herring spawning **sensitivity is medium to high** due to the low tolerance and adaptability to the direct removal of suitable sediment. However, recoverability of herring to a loss of potential spawning habitat is considered to be high at the regional scale.

In terms of the spatial overlap with the receptor, there is limited overlap between the aggregate areas PIZ (current and proposed) and the total herring spawning habitat in the South Coast MAREA region (8.43%). This results in a low likelihood of interaction based on low confidence of the data and small degree of overlap between the effect and the receptor.

The effect will occur on a routine basis and be of medium term duration, based on the licence term. It is unlikely that the sediment suitable for potential herring spawning will be completely removed by the dredging process within the licensed areas, furthermore; there is a large amount (3,697.4 km^2) of potentially suitable, and already utilised, herring spawning habitat outside the PIZs of the aggregate areas within the South Coast MAREA region.

Based on the low level of likely exposure, given the wider habitat available within the South Coast MAREA region and beyond, the medium magnitude of effects and the medium to high receptor sensitivity, the significance of the overall impact of seabed removal to the herring populations is, therefore, considered to be of ***minor significance***.

This significance differs from the impact of seabed removal to demersal spawners that are identified within the South Coast MAREA as not significant (EMU, 2012), since sediment type has since been considered as a parameter for identifying potential herring spawning, and was not previously considered by the South Coast MAREA.

4.1.2 Direct removal of eggs in the PIZ

The physical action of aggregate extraction and the removal of seabed may result in the direct removal of eggs that may be deposited on the sediment following spawning of Atlantic herring. An impact to reproductive success may occur if dredging takes place during a time when eggs are deposited on the seabed, because they are likely to become unproductive when transported into the dredge hopper.

The frequency of the effect of egg removal is considered be routine as it would occur within the PIZ when aggregate extraction is actively being undertaken, duration is short term and frequency routine. Therefore the effect has a **medium magnitude**.

The eggs are unable to detect or react to the change once they are deposited, and therefore have a low adaptability. They are assessed has having a medium tolerance as herring will be able to tolerate small fluctuations in breeding success, but some change may be detectable. The recoverability is considered to be high as the change to population is anticipated to be relatively small. Overall the herring eggs are assessed as having **low sensitivity**.

There is limited spatial overlap between the aggregate areas PIZ (current and proposed) and the total herring spawning habitat in the South Coast MAREA region (8.43%).

The overall impact of the direct removal of eggs is assessed as being **not significant**.

4.1.3 Alteration of habitat structure in the PIZ

The continual targeting of coarser sediments, and deposition of fine sediments from dredger overspills, may lead to changes in the sediment composition within the South Coast MAREA region. As spawning occurs exclusively over coarser grounds, herring spawning habitat may be at risk of fining of sediment from dredging activities (Tillin *et al*., 2011).

The effect will have an extent that is limited to the PIZs of the licensed aggregate extraction areas. The frequency will be routine, as all aggregate extraction areas are located over suitable herring spawning habitat, and any dredging within these areas will cause an effect. Although monitoring is likely to indicate whether a change to habitat structure is occurring, if it does occur, the duration is likely to be medium-term as it may take >1 year for the habitat to reach equilibrium following the cessation of dredging. Therefore, the effect has a **medium magnitude**.

Changes in sediment composition may result in herring having low recoverability, adaptability and tolerance as herring show a degree of spawning site fidelity, but are able to recover regionally due to their known presence within the wider South Coast MAREA region. However, it is unlikely that the effects will result in complete loss of suitable habitat (i.e. has medium adaptability and tolerance). As a result, herring have been assessed as having **medium sensitivity**.

Given the spatial overlap of the effect with only a small proportion of available habitat within the region and beyond and the low confidence in the data and ability of the data to indicate herring spawning habitat, the overall impact of the alteration to habitat is assessed to be of **minor significance**.

This significance differs from the impact of sediment alteration to demersal fish spawning that is identified within the South Coast MAREA as not significant (EMU, 2012), since sediment type has since been considered as a parameter for identifying potential herring spawning, and was not previously considered by the South Coast MAREA.

4.1.4 Recovery of suitable habitat to support future possible spawning activity (re-colonisation)

Following the cessation of dredging, the licence holders are required to leave a capping layer of aggregate resource of at least 0.5 m, which is similar in nature to that which existed before the commencement of dredging. The effect of leaving suitable habitat means that the effect of dredging is not permanent, and will allow re-colonisation of the areas that either become exclusion zones while the licences are still in place, or are no longer dredged following the expiration of the licence.

The effect of leaving a layer of resource is considered mitigation for herring given suitable habitat will still exist. The magnitude is **low to medium magnitude** due to the short term duration, routine frequency and extent within the PIZ. The sensitivity is considered **low to medium** given herring will have a greater degree of adaptability and recoverability should similar habitat exist post dredging. Therefore the overall impact is of ***not significant***.

4.1.5 Smothering of eggs in the SIZ

Herring egg development has been assessed as not being "impaired by suspended sediment dosages of 300 and 500 mg/l for 1 d" (Wilber and Clarke, 2001); and the mortality and embryonic development is not affected by exposure to concentrations of silt between 5 to 300 mg/l for 10 days, nor by short term exposure to a 500 mg/l suspension of silt (Birklund and Wijsman, 2005). Despite the shown tolerance to high suspended sediment concentration (SSC), sediment deposition is expected to be detrimental for eggs and juveniles unless the excess of sediment is removed rapidly by currents (Birklund and Wijsman, 2005).

The frequency of the effect of sediment deposition on herring eggs is assessed as routine as it would occur during normal dredging operations. The duration is anticipated to be short-term, as the fine sediment is expected to disperse via natural hydrodynamic processes. The extent is considered to be localised (i.e. within the SIZs), which are localised and defined as the precautionary sediment plumes set out in the South Coast MAREA (see HR Wallingford, 2010). The degree of deposition would decrease with distance from the dredger. The SIZs of the current and proposed aggregate areas have been assessed as having generally low confidence in their potential to support herring spawning. However, parts of the SIZs overlap with areas for which there is moderate confidence due to the presence of IHLS data. Overall the effect is assessed as having a **low to medium magnitude**.

The eggs are assessed as having a **medium sensitivity** as they will have a low adaptability, a medium tolerance to changes in abundance, and medium recoverability.

Taking the spatial overlap into account and low confidence in the data, the overall impact of sediment deposition on herring eggs is assessed to be of ***minor significance***.

This significance differs from the impact of smothering to demersal fish spawning that is identified within the South Coast MAREA as not significant (EMU, 2012), since sediment type has since been considered as a parameter for identifying potential herring spawning, and was not previously considered by the South Coast MAREA.

4.1.6 Fining of suitable habitat in the SIZ

This impact is similar to that outlined in Section 4.1.3; however, the extent of the effect will be wider as it would apply to all the SIZs (i.e. localised). The effect is considered to have a **medium magnitude**, based on the routine frequency, short-term duration and localised extent.

The receptor is assessed as having **medium sensitivity**, as it is anticipated to have medium adaption and recoverability, and low tolerance. However, it is unlikely that the effects will result in complete loss of suitable habitat, enabling some adaption and tolerance.

Based on the low level of spatial overlap compared to that available across the region and low confidence in the data overall the impact of the fining of sediment in the SIZs is assessed to be of ***minor significance*** to herring.

This significance differs from the impact of fine sediment dispersal to demersal fish spawning that is identified within the South Coast MAREA as not significant (EMU, 2012), since sediment type has since been considered as a parameter for identifying potential herring spawning, and was not previously considered by the South Coast MAREA.

4.1.7 Summary of Impacts

Table 4.1 summarises the potential impacts on herring from marine aggregate extraction within the South Coast MAREA region.

Table 4.1 Summary of the significance of impacts on herring from marine aggregate extraction within the South Coast MAREA region

Effect	Significance	Rationale
Direct removal of suitable sediment in the PIZ	Minor significance	Based on the medium magnitude of effects, the medium to high sensitivity and the limited spatial overlap given the wider habitat available, the cumulative impact of direct sediment removal on potential herring spawning is considered to be of minor significance in the regional context.
Direct removal of eggs in the PIZ	Not significant	Based on the medium magnitude of effects, the low sensitivity and the limited spatial overlap given the wider habitat available, the cumulative impact of direct removal of eggs in the PIZ is considered to be not significant in the regional context.
Alteration of habitat structure in the PIZ	Minor significance	Based on the medium magnitude of effects, the medium sensitivity and the limited spatial overlap given the wider habitat available, the cumulative impact of alteration of habitat structure in the PIZ is considered to be of minor significance in the regional context.
Recovery of suitable habitat to support future possible spawning activity within the PIZ	Not significant	Based on the low to medium magnitude of effects, the low to medium sensitivity and the limited spatial overlap given the wider habitat available, the cumulative impact of recovery of suitable habitat to support future possible spawning activities within the PIZ is considered to be not significant in the regional context.
Smothering of eggs in the SIZ	Minor significance	Based on the medium magnitude of effects, the medium sensitivity and the low level of spatial overlap given the wider habitat available, the cumulative impact of smothering of eggs is considered to be of minor significance in the regional context.

Effect	Significance	Rationale
Fining of suitable habitat in the SIZ	Minor significance	Based on the medium magnitude of effects, the medium sensitivity and the low level of spatial overlap given the wider habitat available, the cumulative impact of smothering of eggs is considered to be of minor significance in the regional context.

Based on the above assessments and the information presented above, the cumulative impact of marine aggregate extraction on potential herring spawning habitats in the South Coast MAREA region is of **minor significance** at the scale of the South Coast MAREA (EMU, 2012).

4.2 STEP 4b – Regional Cumulative Assessment

4.2.1 Introduction

This section presents the findings of the Cumulative Impact Assessment (CIA) for potential impacts to Atlantic herring potential spawning habitat in the South Coast MAREA region. This assessment includes all industries that may cause effects that could interact with the effects resulting from marine aggregate dredging. The following industries are considered in the CIA:

- All potential marine aggregate activity;
- Offshore renewables;
- Commercial fishing (trawl and dredge);
- Disposal sites; and
- Cables and pipelines.

It should be noted that the cable and pipeline routes include both current and predicted export cable route pathways for proposed wind farm developments, which are assessed as being worst case scenario footprints for future years, i.e. the route encompasses the greatest amount of herring spawning habitat. Cable routes have been buffered by 300 mm to give an area to polylines in GIS.

4.2.2 Methodology and study area

The methodology aligns with the worst case rationale used within the South Coast MAREA (EMU, 2012). This rationale assumes that the application areas are representative of the PIZ, in that the Active Dredge Zone (ADZ) may be elected anywhere within the application area.

This approach has also been applied to the footprints of potential projects for other industries:

- Offshore renewables - entire pre-application areas;
- Cables and pipelines - 300 mm diameter along the entire proposed cable route; and
- Commercial fisheries - ICES sub-rectangle (each is approximately 3.5 x 5.5 km) in which the relevant fishing activity has been recorded VMS data for the years 2007 to 2011.

The SIZs for aggregate extraction activities have also been considered within the assessment; the SIZ indicates the area of seabed which may experience deposition of sediment or smothering caused by the dredging activity. These have been based on the outputs of the high level plume study (HR Wallingford, 2010) undertaken to support the South Coast MAREA (EMU, 2012). The resulting SIZ footprints for aggregate extractions were based on peak concentrations likely to be experienced and an overestimation of the distance over which plumes will be dispersed; therefore providing a precautionary prediction of indirect impacts (HR Wallingford, 2010). The estimation of the SIZs for other projects or industries is not feasible where the information is not publically available, or where projects have not yet been designed. Therefore, only the PIZ has been defined quantitatively.

The two dimensional extents (i.e. the footprints) of each industry/activity have been derived using Geographic Information Systems (GIS) software. The extent to which these overlap with preferred potential herring spawning habitat (i.e. sandy Gravel and Gravel) and marginal potential herring spawning habitat (i.e. gravelly Sand) have been calculated to give an estimate of the areas of potential habitat disturbance, proportional to the area of habitat available.

The study area is defined as the South Coast MAREA region. The footprints of the industries that fall within this area and overlap the habitat suitable for herring spawning have been considered within this assessment. The total area of preferred herring spawning habitat (Gravel and sandy Gravel) within the South Coast MAREA region is estimated to be approximately 3,201 km^2, and the total area of marginal (gravelly Sand) potential herring spawning habitat for herring spawning in the South Coast MAREA region is estimated to be approximately 831 km^2. Combined this gives a total area of 4,031 km^2 of potential herring spawning habitat within the South Coast MAREA region.

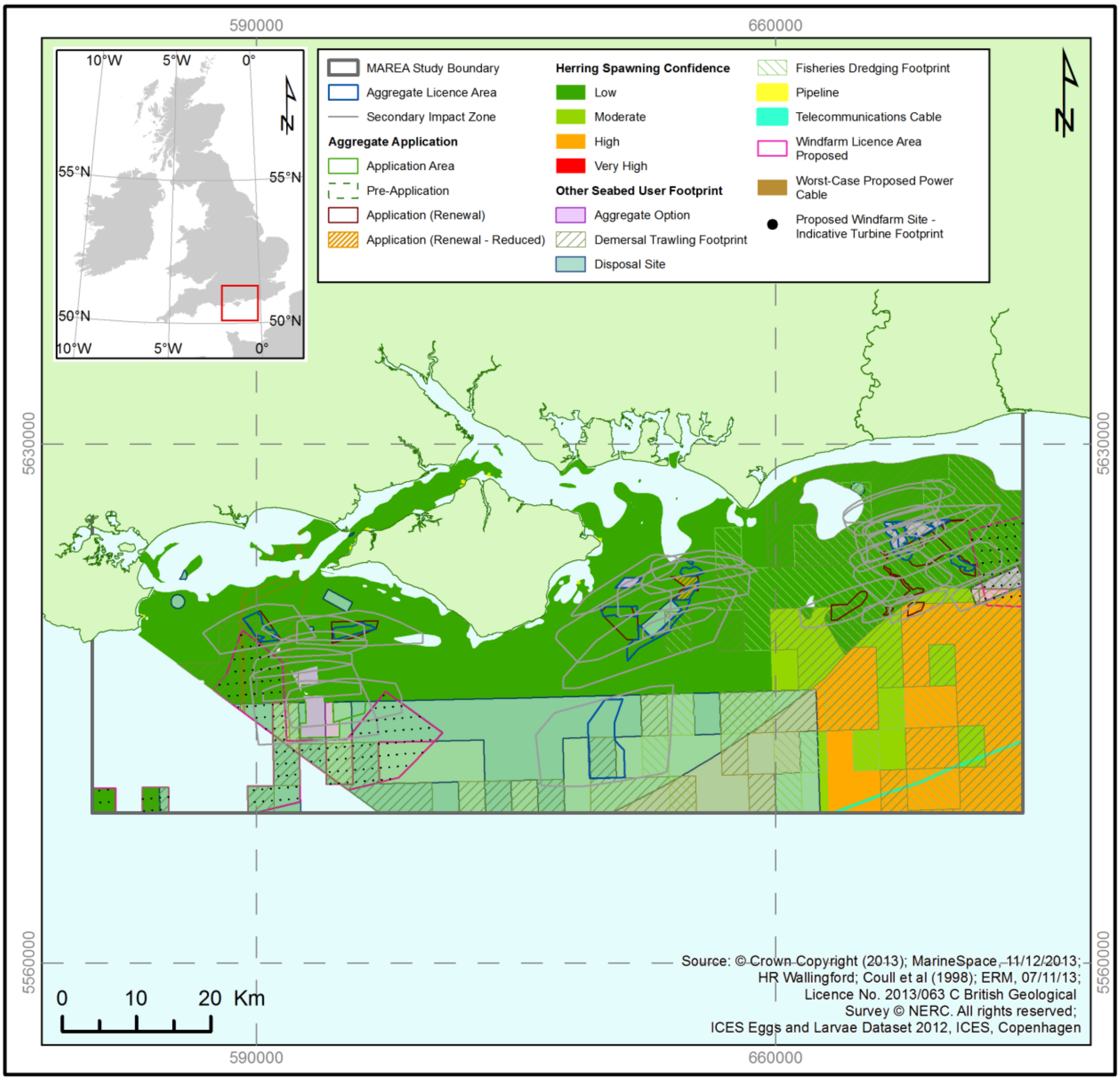
4.2.3 Assessment of industries

Percentage overlaps of each sector on potential herring spawning habitat have been calculated as for the aggregate extraction areas. These are presented in Table 4.1. These figures allow an insight to be gained into the regional footprint of each seabed user against which the footprint of regional aggregate extraction can be contextualised.

A map of all seabed users within the South Coast MAREA region are presented with respect to very high, high, moderate and low confidence areas of seabed to support potential herring spawning is shown in Figure 4.1.

Table 4.1 Regional footprint of all seabed users considered in this assessment overlapping with potential herring spawning habitat areas in the South Coast MAREA region.

	Percentage of area overlapped classified as very high confidence	Percentage of area overlapped classified as high confidence	Percentage of area overlapped classified as moderate confidence	Percentage of area overlapped classified as low confidence
Aggregate extraction (current and proposed) including SIZ	0.00	0.28	0.70	7.45
Commercial fishing (trawl gear types)	0.00	13.28	8.29	21.01
Commercial fishing (dredge gear types)	0.00	13.56	7.74	13.58
Disposal sites	0.00	4.53	10.97	13.29
Proposed wind farm option areas	0.00	0.27	1.38	6.72
Proposed wind farm sites (indicative turbine footprint)	0.00	<0.01	<0.01	0.02
Proposed wind farm worst case cable route option	0.00	<0.01	<0.01	<0.01
Telecommunication cables	0.00	<0.01	<0.01	0.00
Pipelines	0.00	0.00	0.00	<0.01



Map Document: (V:\J1132381_Herring_and_Sandeel_Mapping_Project\3_Plots\2_Draft\20131108 Updates\Q2381_South_Coast_Region_Herring_Cumulative_RJM_20131211.mxd) 11/12/2013 -- 14:19:06

Figure 4.1 Footprint of all industries within the South Coast MAREA region

4.2.3.1 <u>Trawl fisheries</u>

Trawl fisheries have an estimated overlap of 1,751.31 km^2 with high, moderate and low confidence areas of seabed within the South Coast MAREA region to support herring spawning. This corresponds to 13.28% of high confidence, 8.29% of moderate confidence and 21.01% of low confidence areas of seabed (Table 4.1). It should be noted that trawl fisheries are estimated to overlap with 53.4% of marginal herring spawning habitat and 39.3% of preferred herring spawning habitat within the South Coast MAREA region.

These approximations may be considered as over-estimates, as fishing activity is considered to take place over an entire ICES sub-rectangle if it has been recorded anywhere within it. However, VMS data is inherently an underestimate of fishing activity, as only vessels of over 15 m in length are included within the data. Demersal trawl fisheries can cause direct disturbance to the seabed and cause depletion of adult, nursery and spawning stock by removal. This effect occurs regularly, on a seasonal basis, over a long duration.

4.2.3.2 Dredge Fisheries

Dredge fisheries have an estimated overlap of 1,434.73 km^2 with high, moderate and low confidence areas of seabed within the South Coast MAREA region to support herring spawning activity. This corresponds to 13.56% of high confidence, 7.74% of moderate confidence and 13.58% of low confidence areas of seabed (Table 4.1). It should be noted that dredge fisheries are estimated to overlap with 42.7% of marginal herring spawning habitat and 33.6% of preferred herring spawning habitat within the South Coast MAREA region.

As with the trawl fishery approximations, these approximations may be considered as over-estimates, as fishing activity is considered to take place over an entire ICES sub-rectangle if it has been recorded anywhere within it. However, VMS data is inherently an underestimate of fishing activity, as only vessels of over 15 m in length are included within the data.As with demersal trawl fisheries, dredge can cause direct disturbance to the seabed and cause depletion of adult, nursery and spawning stock by removal. This effect occurs regularly, on a seasonal basis, over a long duration.

4.2.3.3 Disposal sites

There are five open registered disposal sites that are still operating within the South Coast MAREA region. These sites are generally used for the disposal of dredged material and are: Swanage Bay (WI110); West Wight (WI091); Needles (WI090); Hurst Fort; (WI080); and Nab Tower (WI060). Disposal is granted on a licence-by-licence basis, and the introduction of new disposal areas cannot be predicted.

Disposal sites have an estimated overlap of 1,183.85 km^2 with high, moderate and low confidence areas of seabed within the South Coast MAREA region to support potential herring spawning. This corresponds to 4.53% of high confidence, 10.97% of moderate confidence and 13.29% of low confidence areas of seabed (Table 4.1). It should be noted that disposal sites are estimated to overlap with 0.7% of marginal herring spawning habitat and 35.1% of preferred herring spawning habitat within the South Coast MAREA region.

It should be noted that these figures reflect both the open and closed disposal sites, however, only open sites have a potential for an on-going cumulative impacts with aggregate extraction within the South Coast MAREA region. Excluding closed disposal sites from the assessment would significantly reduce the percentage overlap with high, moderate and low confidence areas of seabed which have the potential to support herring spawning.

Dredge disposal will lead to a change in the existing sediment composition, dependant on the source location of the dredged sediments, though burial. This may alter the habitat suitability of the area. The effects of disposal are likely to be frequent, however, registered disposal areas are located in areas that are considered to have few influences on the surrounding human and biological environment.

4.2.3.4 Offshore renewables

Proposed wind farm option areas have an estimated overlap of 344.17 km^2 with high, moderate and low confidence areas of seabed within the South Coast MAREA region to support potential herring spawning. This corresponds to 0.27% of high confidence, 1.38% of moderate confidence and 6.72% of low confidence areas of seabed (Table 4.1). It should be noted that proposed wind farm option areas overlap with 7.9% of marginal herring spawning habitat and 6.6% of preferred herring spawning habitat within the South Coast MAREA region. It should be noted that these figures are likely to be an overestimate because consideration is given to the area of search rather than actual areas of lease.

The indicative turbine footprints within the proposed wind farm option areas have an estimated overlap of 0.80 km^2 with high, moderate and low confidence areas of seabed within the South Coast MAREA region to support herring spawning. This corresponds to 0.0005% of high, 0.004% of moderate and 0.02% of low confidence areas of seabed (Table 4.1). It should be noted that the indicative turbine footprints overlap with 0.01% of marginal and 0.04% of preferred potential herring spawning habitat within the South Coast MAREA region.

The worst case proposed power cables have an estimated overlap of 0.03 km^2 with high, moderate and low confidence areas of seabed within the South Coast MAREA region to support potential herring spawning. This corresponds to 0.00001% of high confidence, 0.0004% of moderate confidence and 0.0008% of low confidence areas of seabed (Table 4.1).

Offshore renewables may cause direct loss of existing habitat due to the placement of infrastructure, or during ground preparation works for foundations and cables. Indirect impacts may occur as a result of smothering or sediment fining following the deposition of a sediment plume caused by the movement of seabed sediment. These effects are considered to occur during the construction of the development. During the operation of the development, occurrences of scour around installations may also contribute to a highly localised change in sediment type.

4.2.3.5 Cables and pipelines

Telecommunication cables have an estimated overlap of 0.001 km^2 with high and moderate confidence seabed within the South Coast MAREA region to support potential herring spawning. This corresponds to 0.00003% of high confidence areas of seabed and 0.000005% of moderate confidence areas of seabed (Table 4.1). Pipelines have an estimated overlap of 0.001 km^2 with low confidence seabed within the South Coast MAREA region to support potential herring spawning. This corresponds to 0.00003% of low confidence areas of seabed (Table 4.1). It should be noted that the total areas for all cables and pipelines within the South Coast MAREA region overlaps with 0.0009% of marginal and 0.0005% of preferred potential herring spawning habitat within the South Coast MAREA region.

Potential maintenance to existing cables and pipelines, or proposed cables and that may be constructed, could cause effects that may also interact with habitat suitable for herring spawning. Existing cables and pipelines may be buried to provide protection and avoid damage to and by fishing gears and vessel anchors. If maintenance is requires, the infrastructure will be required to be brought to the surface and replaced; causing direct disturbance to the seabed sediments. Also, proposed cables will require burial along the entire length. This effect does not occur over the entire cable route at one time, but depending in the burial method, may cause a plume that may lead to smothering of sediment fining.

4.2.4 Marine aggregates, relative to other activities

In terms of contextualising the contribution of marine aggregate extraction to the regional cumulative impacts, it can be seen that marine aggregate extraction overlaps with 0.28% of high, 0.70% of moderate and 7.45% of low confidence areas of seabed to support potential herring spawning activity.

Ranking the percentage overlap with high, moderate and low confidence areas of seabed from each industry, from highest to lowest, leads to a standing of:

1. **Trawl fisheries** – overall, overlaps with 42.58% of high, moderate and low confidence areas of seabed within the South Coast MAREA region;
2. **Dredge fisheries** – overall, overlaps with 34.88% of high, moderate and low confidence areas of seabed within the South Coast MAREA region;
3. **Disposal sites** – overall, overlaps with 28.79% of high, moderate and low confidence areas of the seabed within the South Coast MAREA region;
4. **Marine aggregates** – overall, overlaps with 8.43% of high, moderate and low confidence areas of seabed within the South Coast MAREA region;
5. **Offshore renewables** – overall, overlaps with 8.39% of high, moderate and low confidence areas of seabed within the South Coast MAREA region; and
6. **Cables and pipelines** – overall, overlaps with 0.00007% of high, moderate and low confidence areas of seabed within the South Coast MAREA region.

4.2.5 Assessment of cumulative significance

It is possible for cumulative impacts to occur outside the South Coast MAREA region, within the range of sub-populations of Atlantic herring. Therefore, the impacts relating to any sub-population distribution will require consideration within a site specific Environmental Impact Assessment, and as part of any Cumulative Impact Assessment.

Cables and pipelines are considered to have a negligible impact on potential herring spawning habitat, due to the <1% spatial overlap and low duration and severity. The impact from offshore renewables and marine aggregates is considered to be minor due to the <10% spatial overlap and low duration, frequency and medium severity. The effect of commercial fishing activity and disposal sites is also considered to be minor; although the extent is medium (i.e. approximately <50%) and frequency is high, the severity is low, as only the topmost sediments are changed, and to a small degree. Overall, the cumulative impact of offshore industries on the suitable sediments for Atlantic herring is considered to be of minor significance.

It is possible that cumulative impacts outside of the South Coast MAREA region have the potential to impact on potential spawning habitat of the sub-population of Atlantic herring within the region, for instance, damage or deterioration of seabed habitats relating to the use of offshore wind farm monopiles. It is also acknowledged that certain sectors such as commercial fisheries are harder to parameterise due to the inter-annual variation.

4.2.5.1 Overall significance statement of impact of aggregate dredging:

The licence and application areas within the South Coast MAREA region have the fifth lowest impact upon potential herring spawning habitat. Regional aggregate extraction overlaps 8.43% of potential spawning habitat.

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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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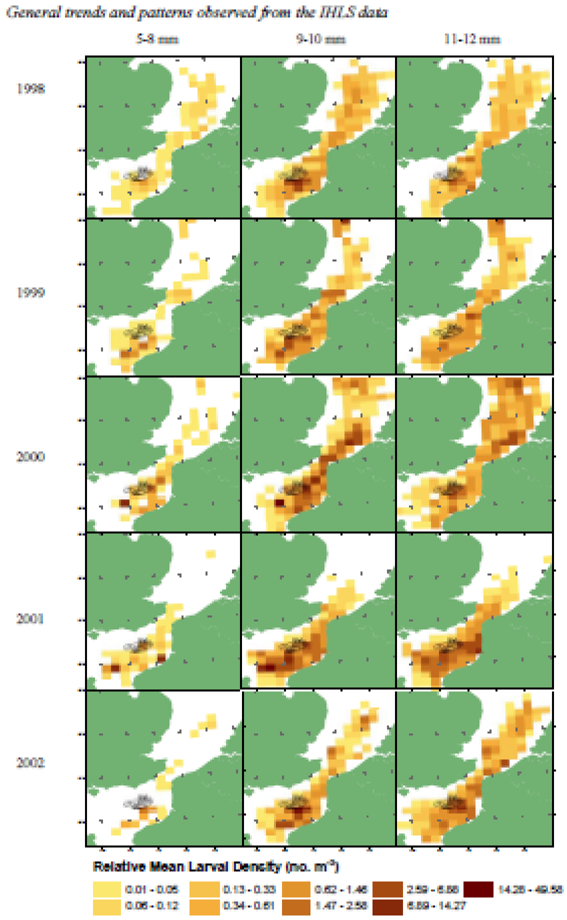
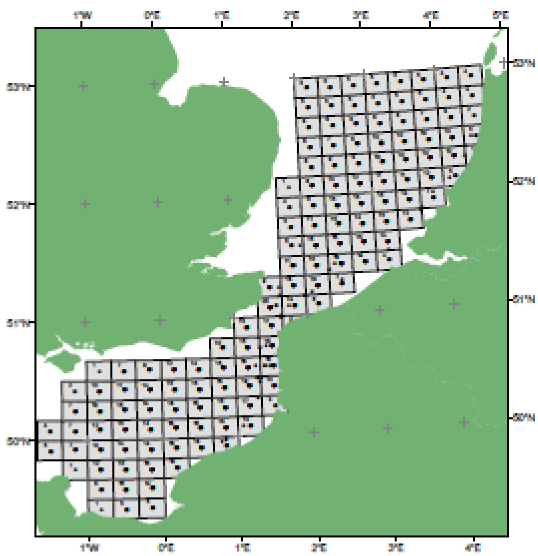
Cefas Caveat	EIA WG Response
The International Herring Larval survey (IHLS) was greater in extent and duration in the past. Now, due to sharp reduction in ship time and number of participating nations the survey now only samples peak spawning locations and at around the peak spawning. While the Downs component is surveyed three times (covering the whole hatching period), all others areas are in general covered only once a year, and most often during the same time period, hence peaks timings can be missed. This pattern is persistent for most of the last 20 years. It is obvious that these gaps must results in larger levels of uncertainty when calculating larvae abundance indices for the North Sea. (ICES 2012). It is important to note that in areas where the IHLS survey was not undertaken is not indicative of no spawning. **MMO Herring Comment 6.3.**	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. 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 (in the main report), 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. The range of IHLS data for the period 1998-2002 provides an additional 5 years of spatial coverage relevant to the Downs and Banks spawning populations as considered in Mills *et al.* (2003). This sets the context for the IHLS data used and enables a distinction between lack of survey data and null data to be made. The figures below from Mills *et al.* (2003) show that there was an extension of the IHLS further offshore into the southern North Sea towards the Dogger Bank and closer inshore through the Anglian and Humber regions during the period 1998-2003 i.e. there has been a reduction in the area of coverage that has been most recently reported in the Herring Assessment Working Report for 2012 (ICES, 2012) used as the basis for the IHLS data analyses and interpolation.



The distribution of IHLS sample stations for the period 1998-2002 is presented below (from Mills *et al.*, 2003).



	The figures presented show that whilst there has been a reduction in the IHLS area from 2002 to 2011, the main distribution of the Downs population is still surveyed and there is little variation between years and the coverage of the Outer Thames and South Coast regions. There has been a reduction on the coverage of the inshore component of the Anglian region. The HAWG report (ICES, 2012) shows that the Humber assessment area in relation to the Banks population has retracted northwards in comparison to the late 1990s/early 2000s. In the case of data voids, other relevant data sources were searched for and identified. The Triton Knoll offshore windfarm ES surveys fill significant gaps for the 'inner' Humber region. Whilst not conducted at exactly the same time as the IHLS to the north, these data are still relevant. Especially considering the MMO's comment that even the IHLS have poor correlation considering the variability of repeated survey during spawning events. Indeed it is important to recognise that the IHLS data are used to inform Cefas advice to the MMO so the caveat being addressed is inherent within the environmental assessment for Atlantic Herring as whole. Further, the IHLS data are only one of several data sets used to build the 'confidence maps'. A key purpose of using multiple data sets was to counter possible gaps in the data. The main outcome of gaps in the IHLS data is a slightly lower level of confidence in such areas but for the reasons explained above this is considered immaterial.
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.	Whilst the IHLS sampling method may be deemed to 'miss' some larvae the data still represents a good indication of larvae distribution and therefore spawning habitat, indeed IHLS data may overestimate the area of potential herring spawning habitat due to larval dispersal from the actual egg site. This adds to the likelihood of the assessment predicting an

MMO herring comment 6.3	overlap between a licence area and a high value potential spawning area (a conservative assessment envelope, as the extent of the spawning bed is effectively over-estimated). Conversely by possibly 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 in main report) 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.
For the purposes of this assessment preferred habitat for herring is based on substrate classification alone. It must be noted that there are other factors, i.e. for herring: raised seabed features, good oxygenation plus other factors, are involved in establishing a ground as suitable for spawning. As a consequence not all areas described as preferred habitat will be suitable for spawning. **MMO Herring Comment 4.1 & 4.5**	As noted above and elsewhere in this assessment, actual potential spawning beds will be 'micro' features in comparison with the macro scale level of mapping undertaken in this assessment. Other site-specific evidence such as that provided by herring fishers who target spawning herring aggregations would need to be sought in order to fully understand the location of such features. The reference to preferred and marginal habitat has been amended to reference preferred and marginal habitat <u>sediments</u>. This acknowledges that they are only one data-layer that is considered with the overall 'heat' mapping assessment methodology. Amended text and sign-posts have been included in the report and an addendum has been provided at the beginning of Appendix A which contains the original methodology. Further, the direct reference to habitat sediment

	extents and determinations based on these areas of extent have been removed from the main body of the report and inserted into Appendix M. However, it is still important to acknowledge that habitat sediment type is an important mapping and assessment data-layer that underpins the other data-layers used in the assessments.
The MMO and RAG have advised that the population level effect of marine aggregate dredging on Atlantic Herring will not be required to be assessed under the MWR application processs. (MMO, 2013). This has been based on the current ICES (2012), Herring Assessment Working Group (HAWG) review on the current sustainable status of Atlantic Herring populations. However, there are concerns about poor recruitment years which are likely to be reflected in the adult population over the coming years i.e. within the 15 year application period of licences	Apparent poor recruitment has not been attributed to any particular factor. However since marine aggregate extraction has been occurring in all subject regions over the decades in which Atlantic Herring stocks have recovered from overfishing it is unlikely that recent poor recruitment can be attributed to habitat change or loss. More likely reasons will be climate change and changes in patterns of primary productivity and prey food availability (Engelhard and Heino, 2006).
It is also important to note that some historic herring spawning grounds which currently have very little or no spawning activity can be re-colonised (subsequent seabed recovery from impacts and ability to support spawning activity over time) (ICES, 2012).	This assessment looks at a wide number of factors that together will indicate both potential and actual spawning grounds.
It is beyond the scope of the CIA carried out here to include all cumulative activities. However, it should be noted that there are potential cumulative impacts from other activities outside of the MAREA regions from national and international sources, and that these are likely to have further, additive, impacts on some areas. **MMO Herring Comment 9.2**	All cumulative activities (Impacts that arise from multiple marine aggregate extraction activities) within each MAREA region have been assessed within this report. In addition, a spatial comparison of in-combination activities (all industrial sectors operating within the same region) has been carried out within this report, both for the MAREA regions and for the wider regional sea area. It is however acknowledged that other in-combination activities may occur in some areas.
Any new data sources concerning cumulative impacts should be included in the site level	Noted. This will also be done for in-combination

CIA.	impacts.
Heat maps generated from overall data confidences are not necessarily indicative of spawning areas. Higher confidence levels indicate that more layers of data are available for that area and do not relay any information about data contents. Hence should not be assumed to be directly related to spawning activity.	The assessment is to identify Atlantic Herring potential spawning habitat. The 'heat' map approach adopted in terms of confidence levels indicates varying degrees of likelihood that an area will be suitable for spawning or will contain spawning beds.
It is acknowledged that the methodology in this report will be subject to periodic review …, and subsequent revised versions may be released as the scientific understanding of Atlantic Herring spawning habitat preferences advances, and/or when new data become available.	Review and update may be a possibility. However once site-specific work at the licence area is undertaken to more fully determine presence or absence of potential spawning beds there will be little value to the marine aggregate companies in updating this study as it will no longer be relevant to management of their activities. The EIA Working Group will be happy to provide the data to any other party who may wish to continue the work.
It is not clear where the fisheries trawl data has been derived from and therefore its accuracy cannot be confirmed. These data needs to be referenced and caveated in terms of the limitations of these data by the EIAWG. The implications and assumptions attributed to the impacts from trawl fishing also need to be verified, referenced and discussed further in the report. **MMO herring comment 9.3**	The VMS data have been sourced from the MMO and accompanied by MEDIN standard metadata. No implications and assumptions attributed to the impacts from trawl fishing are made within the report, either the consultation version 0.8 that this comment 9.3 is based upon or within this final report. Statements made regarding trawl fisheries detail extent of footprint of the activity and relate this in comparison with the 'heat' map classes and other industrial seabed user sectors. Statements of assessment have been clarified within the relevant text in the report to preclude misinterpretation of the determinations and statements.

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. From January 2005 all UK fishing vessels over 15 metres in overall length were required to have installed on board a satellite tracking device. Since January 2012 vessels greater than or equal to 12 m have a requirement to install these systems.	Noted and the extent of the additional footprint of the less that 12 m fleet would need to be established by other means but that is beyond the scope of this study.

Appendix L References

Engelhard G.H., and Heino M., 2006. Climate change and condition of herring (*Clupea harengus*) explain long-term trends in extent of skipped reproduction. *Ocealogia*, 149, 593-603.

International Council for the Exploration of the Sea (ICES), 2012. *Report of the Herring Assessment Working Group for the Area South of 62 N (HAWG)*, 13 - 22 March 2012, Copenhagen, Denmark. ICES CM 2012/ACOM:06. 835 pp.

Mills C., Eastwood P.D. and Rogers S.I., 2003. Herring spawning grounds in the eastern English Channel. CEFAS (FB-ECOS) Working Paper – Herring Spawning Grounds in the Eastern English Channel. Pp 9.

MarineSpace Ltd, ABPmer Ltd, ERM Ltd, Fugro EMU Ltd and Marine Ecological Surveys Ltd, 2013. *Environmental Effect Pathways between Marine Aggregate Application Areas and Sandeel Potential Spawning Habitat: Regional Cumulative Impact Assessments*. Version 1.0. A report for BMAPA.

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.

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Appendix M: Seabed habitat sediment maps

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M1. Potential spawning habitat resource – wider regional sea area

As presented in Table M1 the spatial coverage for the wider regional sea area, sourced from the British Geological Survey (BGS) SBS v3 data-layer, covers a total of 134,549 km^2, and extends from the Firth of Forth south across the central and southern North Sea, through the straits of Dover into the eastern English Channel, and across the south coast of England (see Figure M3). Within this, the total area of preferred and marginal habitat sediment with the potential to support Atlantic Herring spawning activity (from the BGS SBS v3 data) covers an area[1] of 35,167 km^2; 26% of the entire wider regional sea area. The area of seabed which is considered to be preferred habitat sediment for potential spawning is 17,045 km^2 whereas the area of marginal potential spawning habitat sediment accounts for 18,122 km^2. It should be noted that the total spawning habitat resource extends beyond the areas of seabed associated with the Banks and the Downs populations; however it is a useful metric that sets the context for potential spawning habitat space for those populations.

Table M1: The extent of Atlantic Herring potential spawning habitat sediment within the central and southern North Sea, the eastern English Channel and the south coast of England. (Data: derived from 1:250,000 scale BGS Digital Data under Licence 2013/063 British Geological Survey. ©NERC.)

BGS Seabed Sediment Data	Humber (km²)	Anglian (km²)	Thames (km²)	South Coast (km²)	Regional Extent of Potential Spawning Habitat Sediment (km²)	Extent of Potential Spawning Habitat Sediment in Wider Regional Sea Area (km²)	Total Wider Regional Sea Area (km²)
Preferred Habitat Sediment	4,581.3	915.3	1,176.2	3,200.7	11,269.0	17,045.9	134,549
Marginal Habitat Sediment	2,001.3	1,505.7	1,418.8	830.7	6,072.6	18,122.2	134,549
Total Potential Spawning Habitat Sediment	6,582.7	3,061.0	2,595.0	4,031.4	17,341.6	35,168.1	134,549

M1.1. Primary Impact Zone footprint – wider regional sea area

Considering the extent of the preferred habitat sediment within the wider regional sea area (17,045 km^2), the area of influence of the Primary Impact Zone (PIZ) associated with marine aggregate dredging activity can be set in context. The preferred habitat sediment PIZ footprint for all licence areas equals 418 km^2 with application areas adding another 612 km^2. Using these values the

[1] All values are rounded down to the nearest whole integer

worst case total PIZ footprint[2] for preferred habitat sediment equates to 1,030 km^2; or 6% of the total extent of the preferred potential spawning habitat sediment in the wider regional sea area.

The area of marginal habitat sediment in the wider regional sea area extends to 18,122 km^2, and interacts with a total licence area PIZ footprint of 139 km^2. Application areas occupy a further 227 km^2 of marginal habitat sediment resulting in a total interaction of 2% of the entire marginal potential spawning habitat sediment in the wider regional sea area. Therefore, the total PIZ footprint for all licence and application areas equates to 1,396 km^2 or 4% of the total potential spawning habitat sediment resource in the wider regional sea area.

M1.2. Secondary Impact Zone footprint – wider regional sea area

Given the extent of the preferred habitat sediment within the wider regional sea area is 17,045 km^2 the area of influence of the Secondary Impact Zone (SIZ) associated with marine aggregate dredging activity can be set in context. The worst case SIZ footprint[3] for preferred habitat sediment equals a seabed area of 3,049 km^2; or 17% of the total extent of the preferred potential spawning habitat sediment within the wider regional sea area.

The area of marginal habitat sediment in the wider regional sea area extends to 18,122 km^2 and interacts with a total SIZ footprint of 1,564 km^2, resulting in exposure of 8% of the marginal potential spawning habitat sediment. Therefore overall, the total SIZ footprint for all licence and application areas with the total potential spawning habitat sediment in the wider regional sea area equates to 4,613 km^2 which is equivalent to 13% of the potential spawning habitat sediment resource in the wider regional sea area.

It is interesting to note that the spatial interaction is not uniform across the wider regional sea area. A notable variation in these distributions can be seen within the Outer Thames estuary where there appears to be a minimal use of the large extent of gravels and sandy gravels by the Downs population (Figure M4 and M8). Similarly the Downs population (as derived from larvae survey data) appears to show a stronger affinity for the offshore gravels and sandy gravels associated with the east English Channel rather than the inshore deposits associated with much of the south coast of England, particularly on the eastern side of the Isle of Wight (Figure M5 and 9).

M1.3. Potential spawning habitat sediment resource – MAREA-scale

Table M2 shows an analysis of the extent of preferred and marginal seabed habitat sediment extracted from each of the 4 MAREA reports considered in this study. The total area of preferred and marginal habitat sediment with the potential to support Atlantic Herring spawning activity (for the 4 MAREA regions considered) covers an area of 16,867 km^2. Of this 11,896 km^2 relates to preferred habitat sediment and a further 4,971 km^2 to marginal potential spawning habitat sediment. A total

[2] This assumes that the total area of seabed within the licence and application area boundaries will be exposed to dredging related habitat removal or abrasion pressures

[3] It is important to note that the worst case SIZ footprints do not consider the sediment loading within sediment plumes. They are purely based upon the MAREA modelled plume footprints and tidal ellipse/prism data (for licence and application areas not considered in the MAREAs) and are a representation of the furthest far-field plume-related effects. These are not necessarily indicative of realistic smothering footprints, but are used to map a worst case footprint using accepted methods for determining marine aggregate environmental effect exposure pathways

of 68% of the seabed habitats found in the 4 MAREA regions has the potential to support Atlantic Herring spawning. In context, the coverage of existing licence areas and application areas (i.e. the PIZs alone, excluding SIZs) within the 4 MAREAs overlap with a total of 999.3 km^2 of potential spawning habitat sediment. This equates to 5.92% of the potential spawning habitat sediment present in the MAREA regions and is equivalent to 4.01% of the total combined extent of the MAREA regional study areas.

Both the BGS and the MAREA seabed sediment data (Table M1 and M2) show that Humber and South Coast regions contain the largest extents of potential spawning habitat sediment compared with the Anglian and Outer Thames Estuary regions. The Anglian and Outer Thames Estuary regions contain greater expanses of sandier seabed sediments, unsuitable for Atlantic Herring spawning activities. This broadscale analysis aligns with the geological and geophysical characterisations presented in the MAREA reports (EMU Ltd, 2012a, 2012b; ERM Ltd, 2010, 2012). In the South Coast MAREA region 91.61% of the seabed sediments consist of habitat with the potential to support Atlantic Herring spawning. Contextually just 261.9 km^2 of this potential spawning habitat sediment may be exposed to a PIZ (assuming worst case i.e. all licence and application areas' PIZ delineated by the area boundary) accounting for 5.72% of all the potential spawning habitat sediment within the South Coast region.

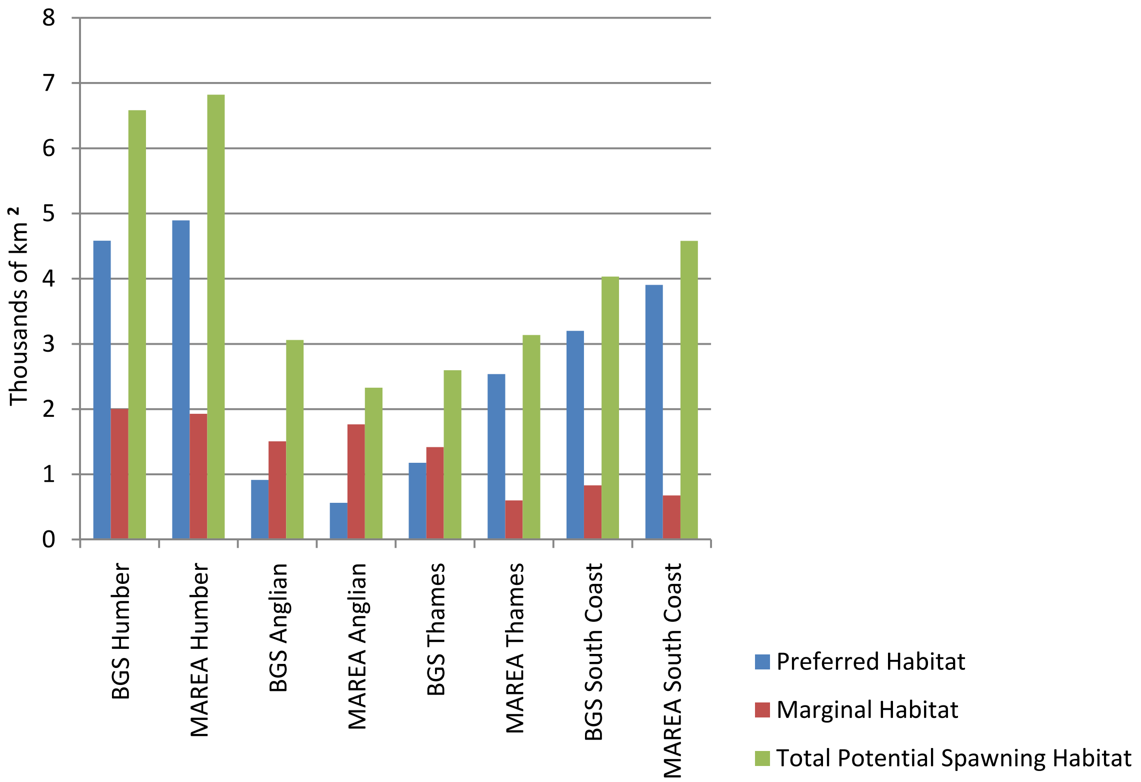
Table M2: The extent of Atlantic Herring potential spawning habitat sediment within the Humber, Anglian, Outer Thames Estuary and South Coast MAREA regions. (Data: EMU Ltd, 2012a, 2012b; ERM Ltd, 2010, 2012)

MAREA Seabed Sediment Data	Regional Extent of Atlantic Herring potential spawning habitat sediment				Total from all MAREA Areas (km²)
	Humber (km²)	Anglian (km²)	Thames* (km²)	South Coast (km²)	
Preferred Habitat sediment	4,893.1	562.5	2,536.5	3,904.0	11,896.0
Marginal Habitat sediment	1,928.9	1,765.6	600.4	676.4	4,971.0
Total Potential Spawning Habitat sediment	6,822.0	2,328.1	3,136.9	4,580.4	16,867.0
Area of MAREA (km²)	9,600.0	4,800.0	5,400.0	5,000.0	24,800.0
% Total of MAREA Total Potential Spawning Habitat sediment	71.1	48.5	58.1	91.6	68.0

*Breakdown of sediments does not conform to the Folk classification divisions. The seabed sediments are mapped with sandy Gravels and gravelly Sands amalgamated into a single mapping unit. As the Atlantic Herring marginal potential spawning habitat sediment is gravelly Sands then the combined mapping unit within the Outer Thames Estuary MAREA makes spatial analysis problematical i.e. the preferred habitat sediment will be over-represented and marginal habitat sediment under-represented.

The data sample density used to underpin both the BGS and MAREA seabed sediment data are comparatively similar, although with a slight bias towards marine aggregate areas in the MAREA data as expected due to the purpose of these studies; to characterise the marine and coastal environment with regard to marine aggregate operations and cumulative environmental effects.

Figure M1: 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 sediments 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

M1.4. 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 M6). 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 sediment and marginal habitat sediment.

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

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 potential spawning habitat screening assessment. The threshold between preferred and marginal spawning habitat sediment sits across the division between sandy Gravel and gravelly Sand (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 M1 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.

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.

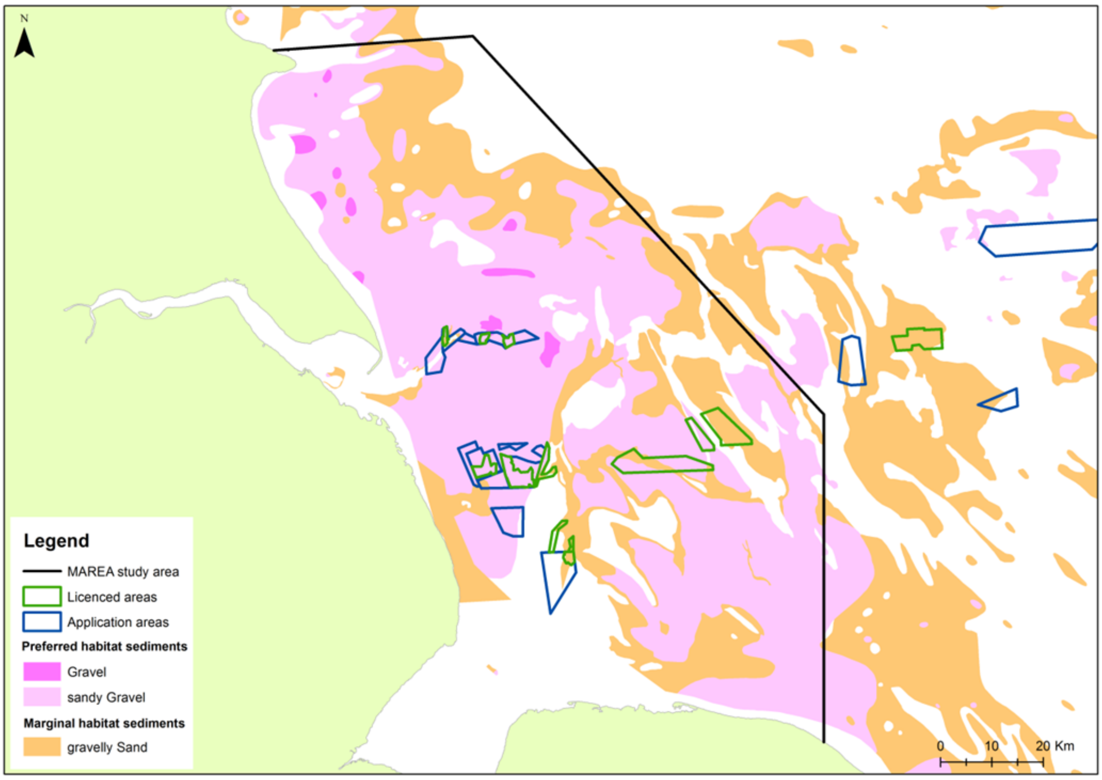
In all the above cases, where Folk sediment classes have been generalised or combined, the lowest confidence is adopted, e.g. the confidence of a combined class of sandy Gravel and gravelly Sand to indicate Atlantic Herring potential spawning habitat sediment is 0 (very low).

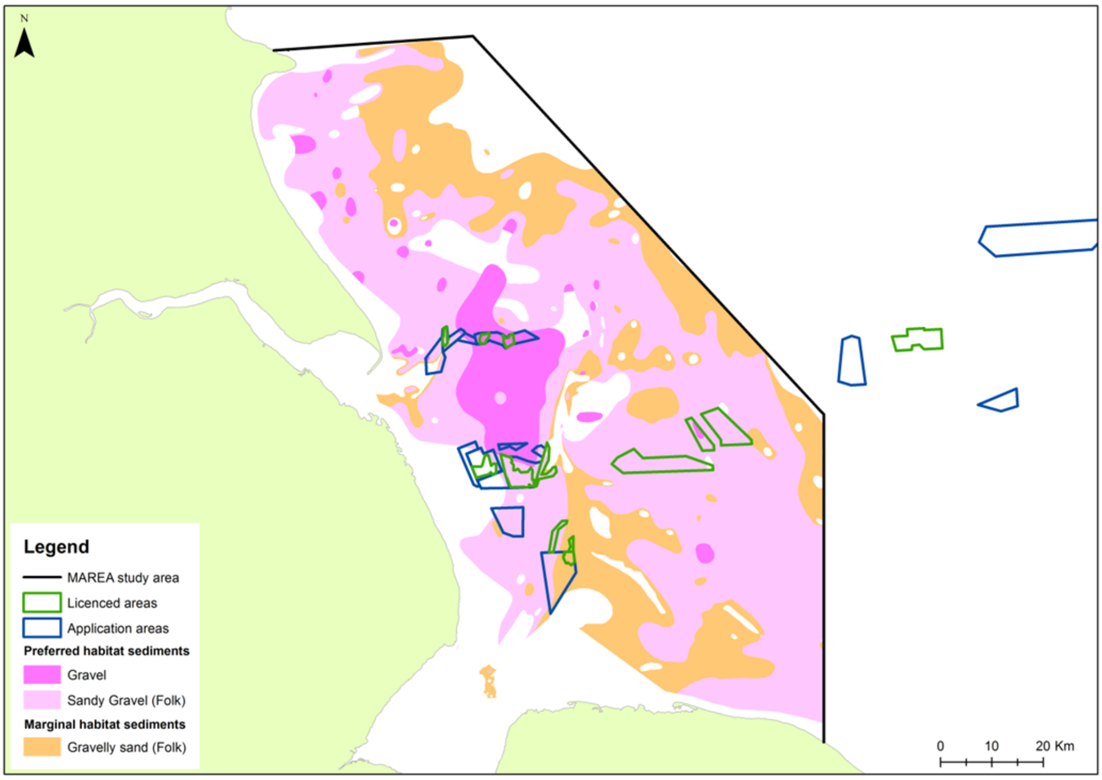
As it was not possible (or necessarily desirable) to combine both the BGS and MAREA seabed sediment data as an indicator of potential spawning grounds, the EIA WG has advised that the best seabed sediment data deemed appropriate are used within the study (and for any particular application area's ES).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

Figure M2: Comparison of the mapped extents of Atlantic Herring potential spawning habitat sediment using BGS (upper) and MAREA (middle) and 'outlier' BGS (lower) data within the Humber region. (Derived from 1:250,000 scale BGS Digital Data under Licence 2013/063 British Geological Survey. ©NERC.; ERM Ltd, 2012)





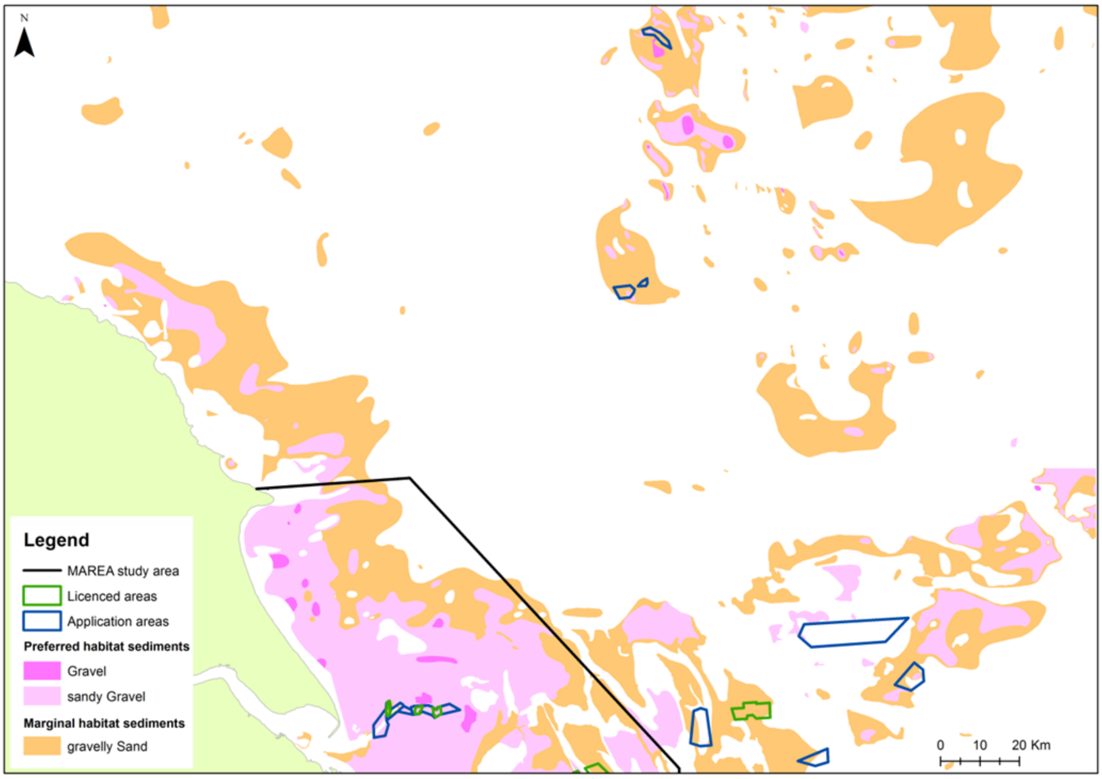
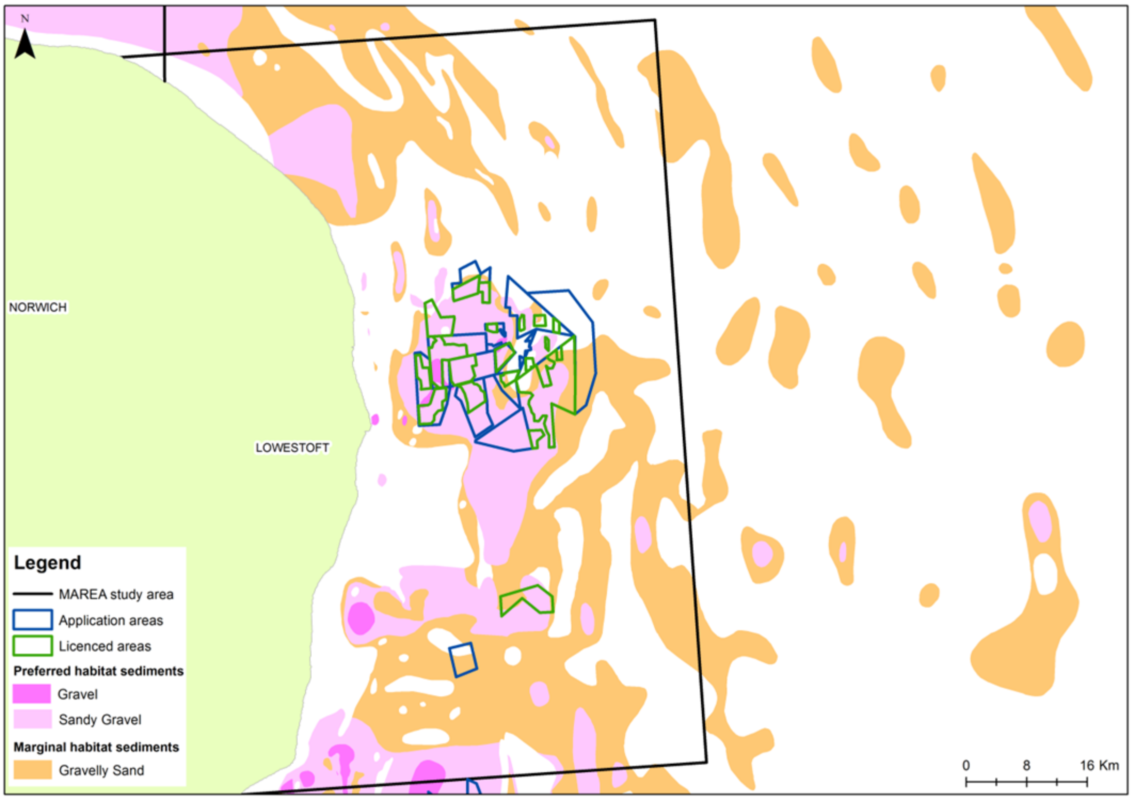

N
Legend
MAREA study area
Licenced areas
Application areas
Preferred habitat sediments
Gravel
sandy Gravel
Marginal habitat sediments
gravelly Sand
0 10 20 Km

Figure M3: Comparison of the mapped extents of Atlantic Herring potential spawning habitat sediment using BGS (upper) and MAREA (lower) data within the Anglian region. (Derived from 1:250,000 scale BGS Digital Data under Licence 2013/063 British Geological Survey. ©NERC.; EMU Ltd, 2012a)



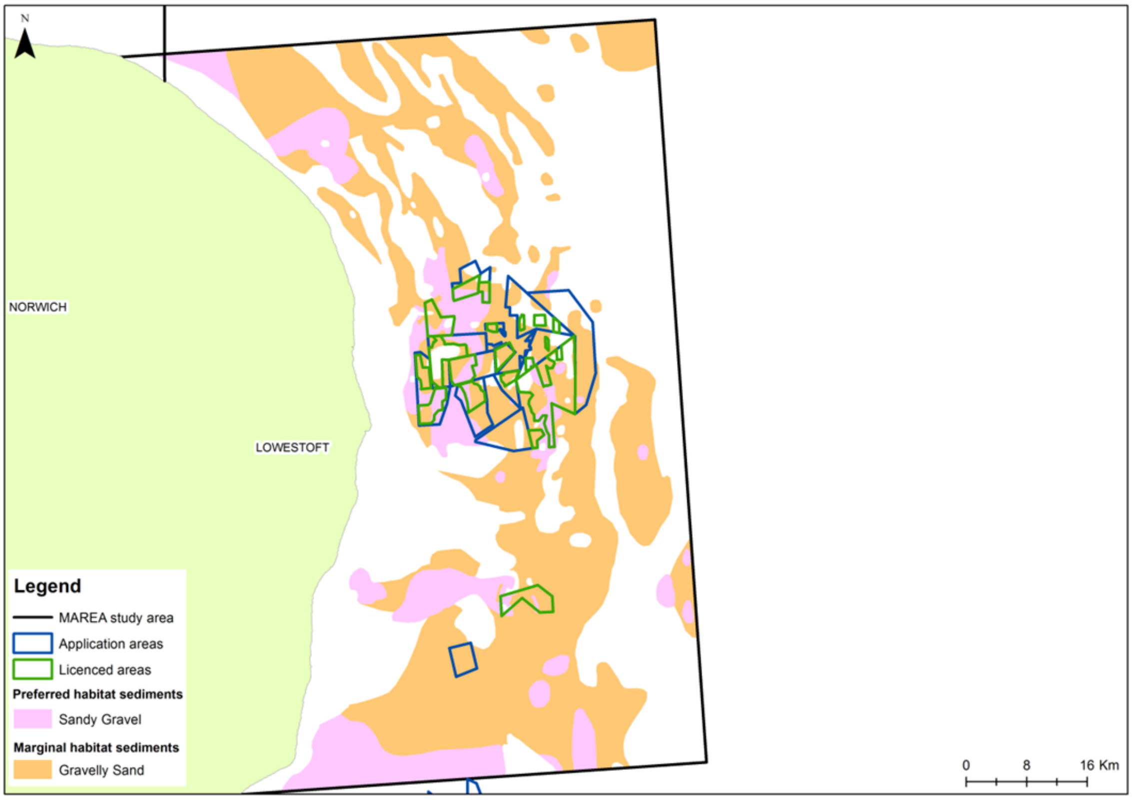
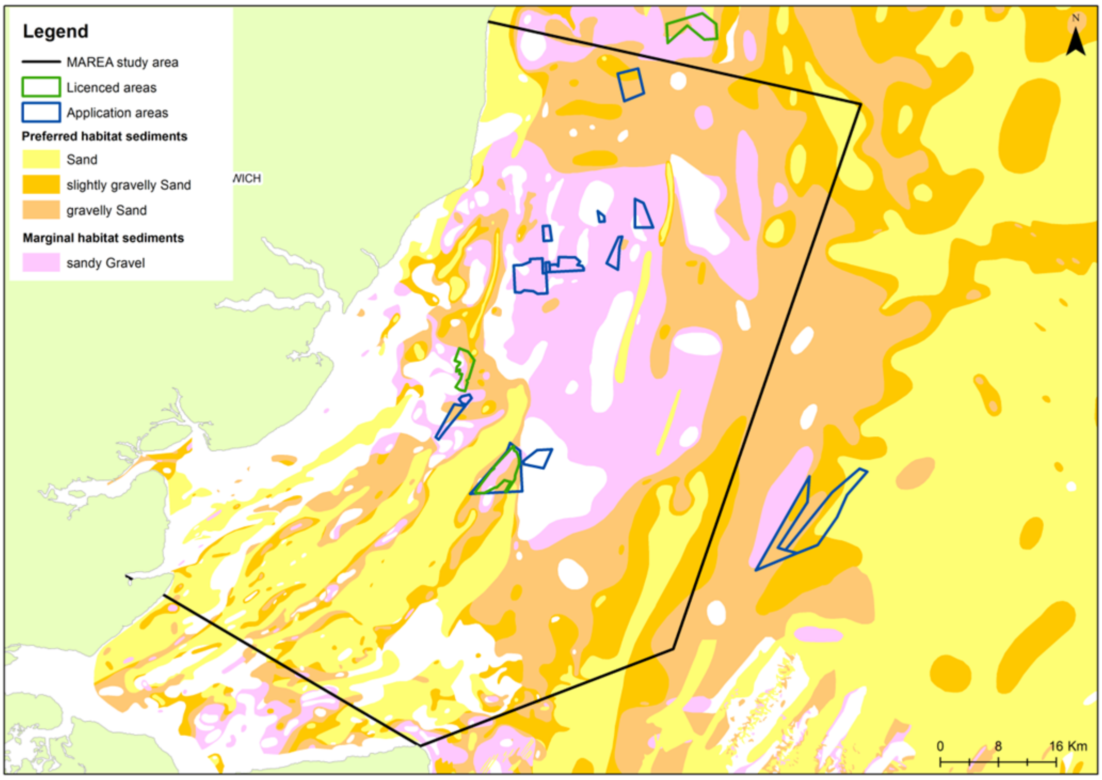


Figure M4: Comparison of the mapped extents of Atlantic Herring potential spawning habitat sediment using BGS (upper) and MAREA (lower) data within the Outer Thames Estuary region. (Derived from 1:250,000 scale BGS Digital Data under Licence 2013/063 British Geological Survey. ©NERC.; ERM Ltd, 2010)



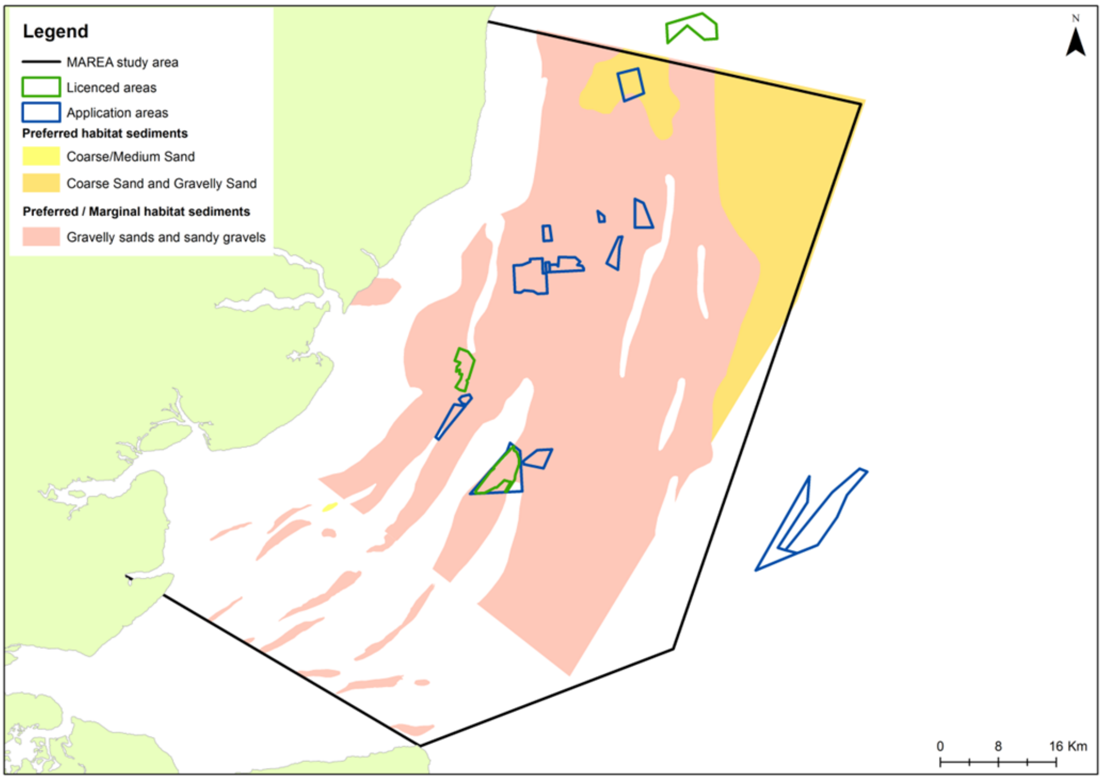
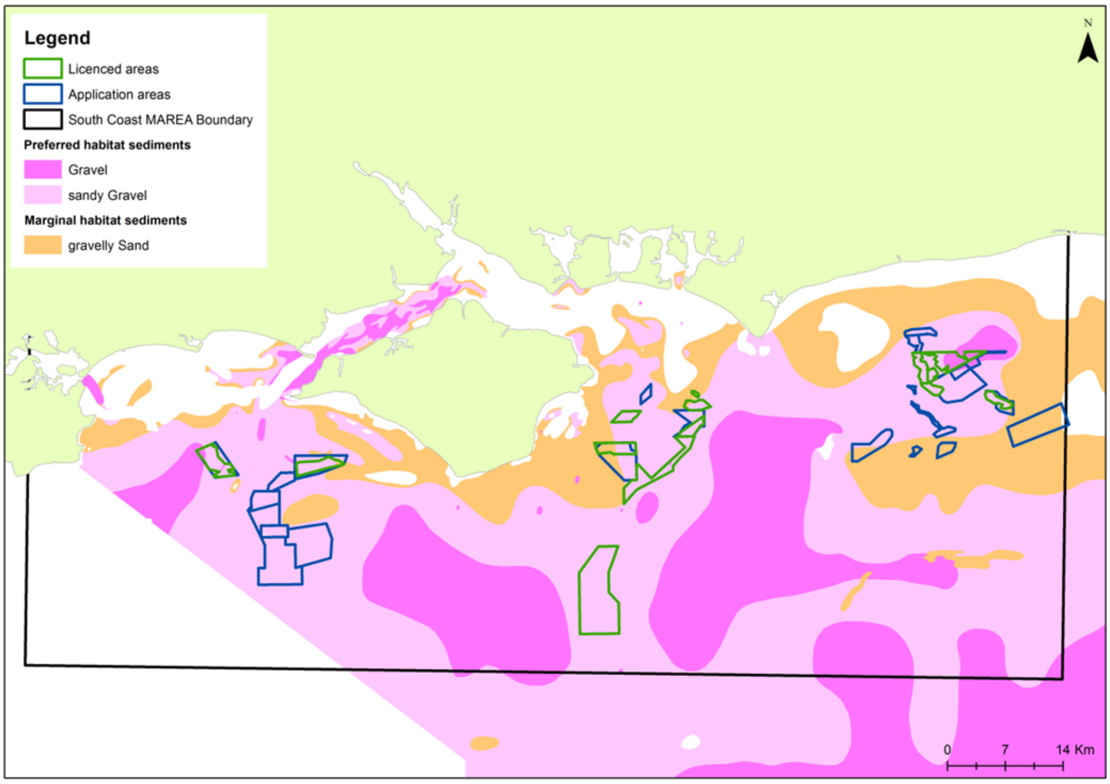
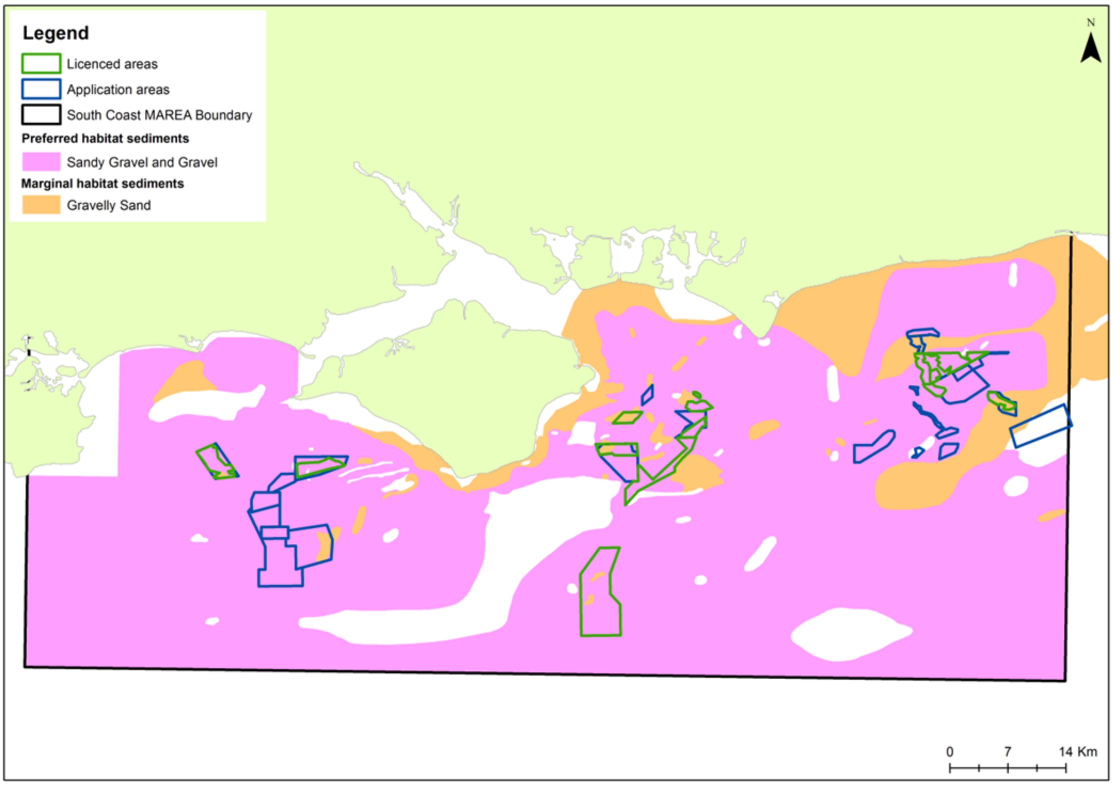


Figure M5: Comparison of the mapped extents of Atlantic Herring potential spawning habitat sediment using BGS (upper) and MAREA (lower) data within the South Coast region. (Derived from 1:250,000 scale BGS Digital Data under Licence 2013/063 British Geological Survey. ©NERC.; EMU Ltd, 2012b)





Figures M6-M9 show the confidence attached, per MAREA region, to each of the BGS and MAREA seabed sediment maps. The confidence scoring reflects the preferred and marginal habitat sediment divisions with a higher confidence associated with preferred habitat sediment than that associated with marginal habitat sediment (Appendix B). The mapping layer confidence scores represent the Total Normalised Score and range from very low to very high (score of 1 to 5 with 1 = very low, 2 = low, 3= medium, 4 = high and 5 = very high).

No more than a score of low confidence (score of 2) for marginal habitat sediment and medium confidence (score of 3) for preferred habitat sediment can be achieved (see Section 2.3.7).

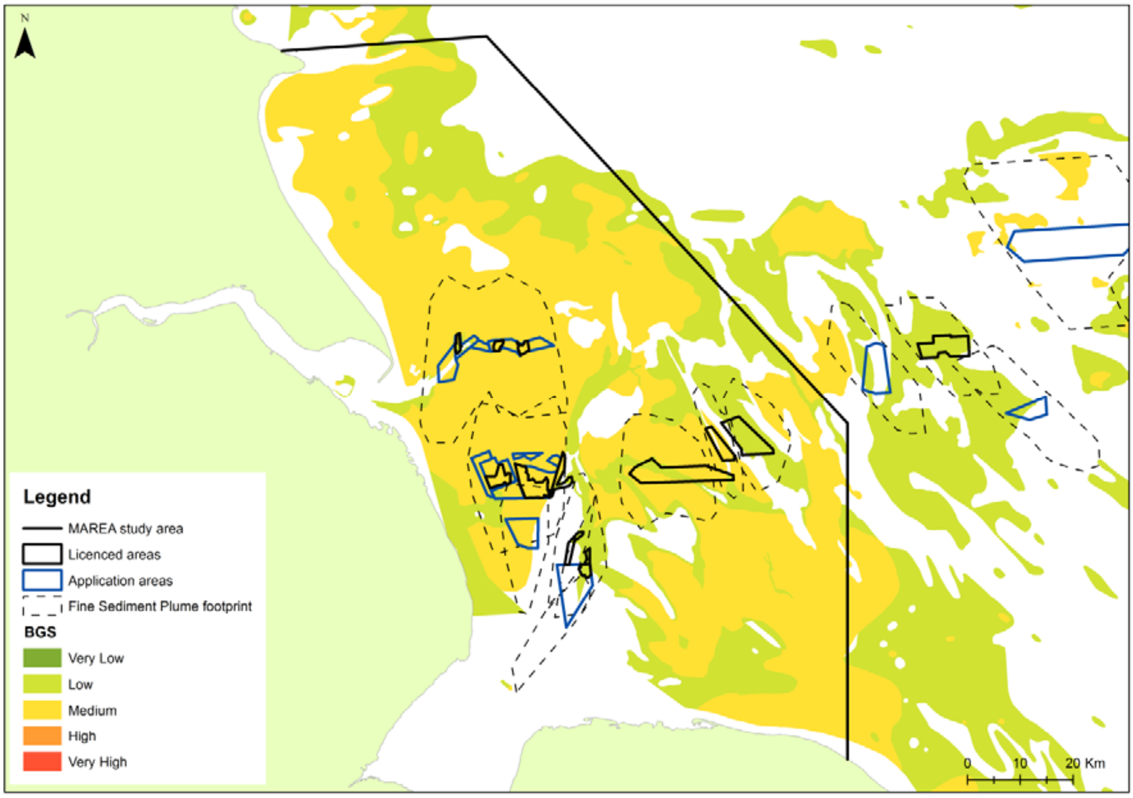
By comparing the confidence maps for the BGS data with the MAREA data it is evident that there are varying levels of confidence between using the data at the MAREA region scale. For the Humber and Anglian regions it is evident that the confidences between the datasets are similar, but that the MAREA data provide an appropriate resolution of sediment distribution and coverage. Therefore, the MAREA data has been used as the seabed sediment base-map for both the Humber and Anglian regions.

For the Outer Thames and South Coast regions the comparison between the MAREA and BGS confidence mapping shows that the BGS data provide high resolution maps when compared with the MAREA data. For the Outer Thames region the BGS presents a much higher confidence in the BGS data due to the appropriate distinction between the preferred and marginal habitat sediment divisions. Further, the BGS data present a more detailed map of the bedforms and seabed sediment distribution. Therefore, both the Stage 1 and 2 assessments within this study have used the BGS data for the Outer Thames region.

There is little difference between the BGS and MAREA maps for the South Coast region, even though Gravel and sandy Gravel sediment classes are mapped together as these divisions are both representative of preferred potential spawning habitat sediment. However, the study decided to use the BGS data for the South Coast regional assessment to synergise the results and determinations with another study that is assessing the environmental effects between marine aggregate areas and sandeel habitat (MarineSpace Ltd, 2013). This is because sandeel marginal habitat sediment is represented by sandy Gravel; therefore use of the MAREA data means that the distinction between sandeel marginal and preferred habitat sediment cannot be mapped.

For the ‘outlier’ application areas (those outside the relevant MAREA region), the BGS seabed sediment data have to be used as no MAREA data are available. This is only applicable to the Humber and Outer Thames regions; all licence and application areas in the Anglian and South Coast regions fall within the relevant MAREA region boundary.

Figure M6: Comparison of the confidence in the Atlantic Herring potential spawning habitat sediment within the Humber region between the BGS (upper) and MAREA data (lower). (Derived from 1:250,000 scale BGS Digital Data under Licence 2013/063 British Geological Survey. ©NERC.; ERM Ltd, 2012)



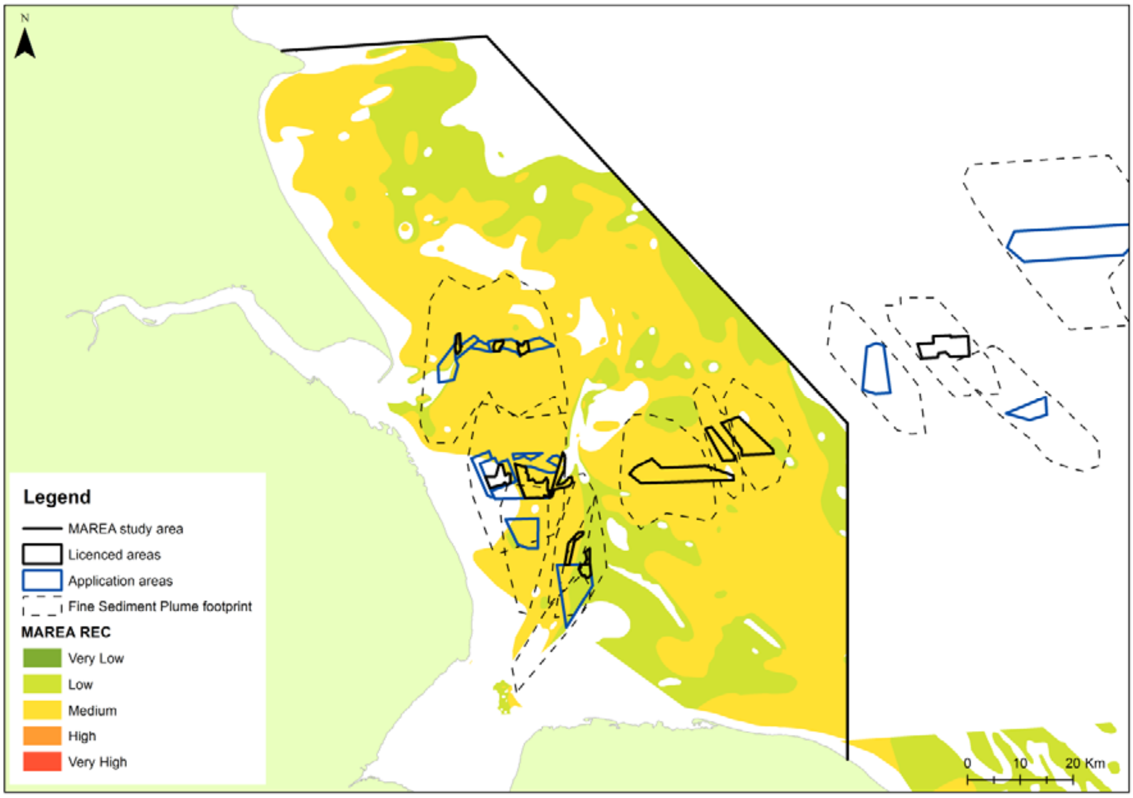


Figure M7: Comparison of the confidence in the Atlantic Herring potential spawning habitat sediment within the Anglian region between the BGS (upper) and MAREA data (lower). (Derived from 1:250,000 scale BGS Digital Data under Licence 2013/063 British Geological Survey. ©NERC.; EMU Ltd, 2012a)

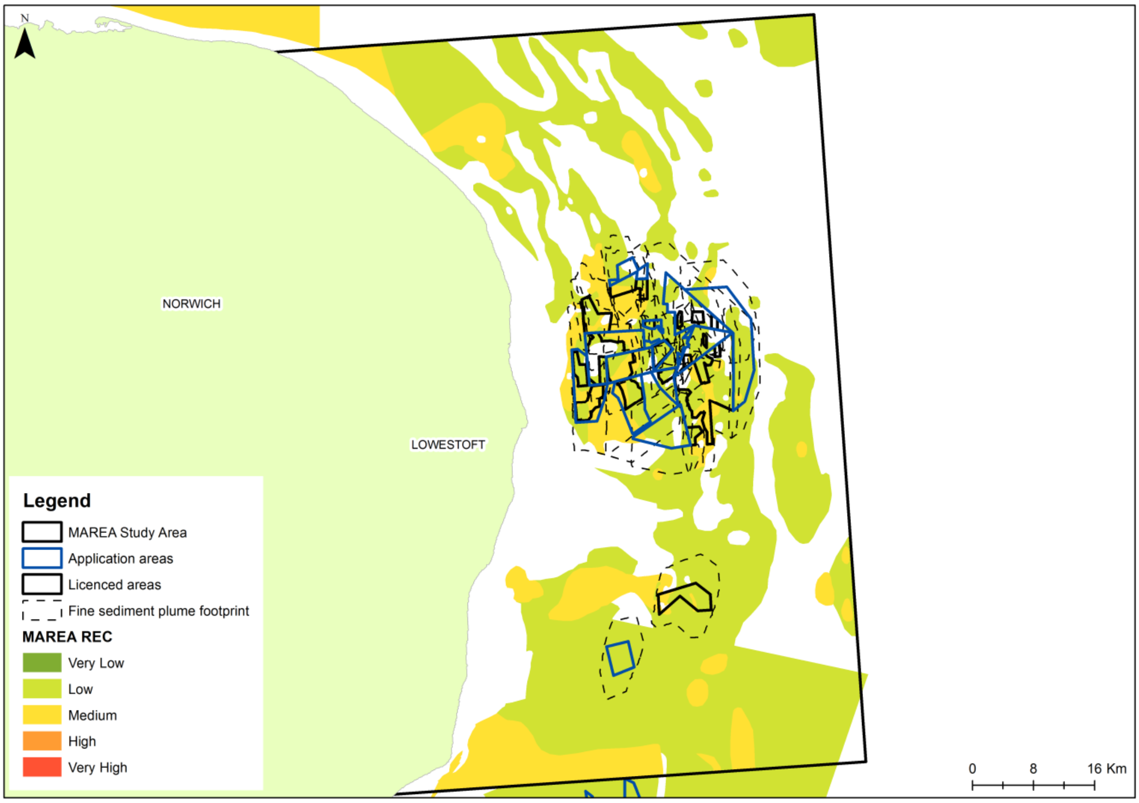
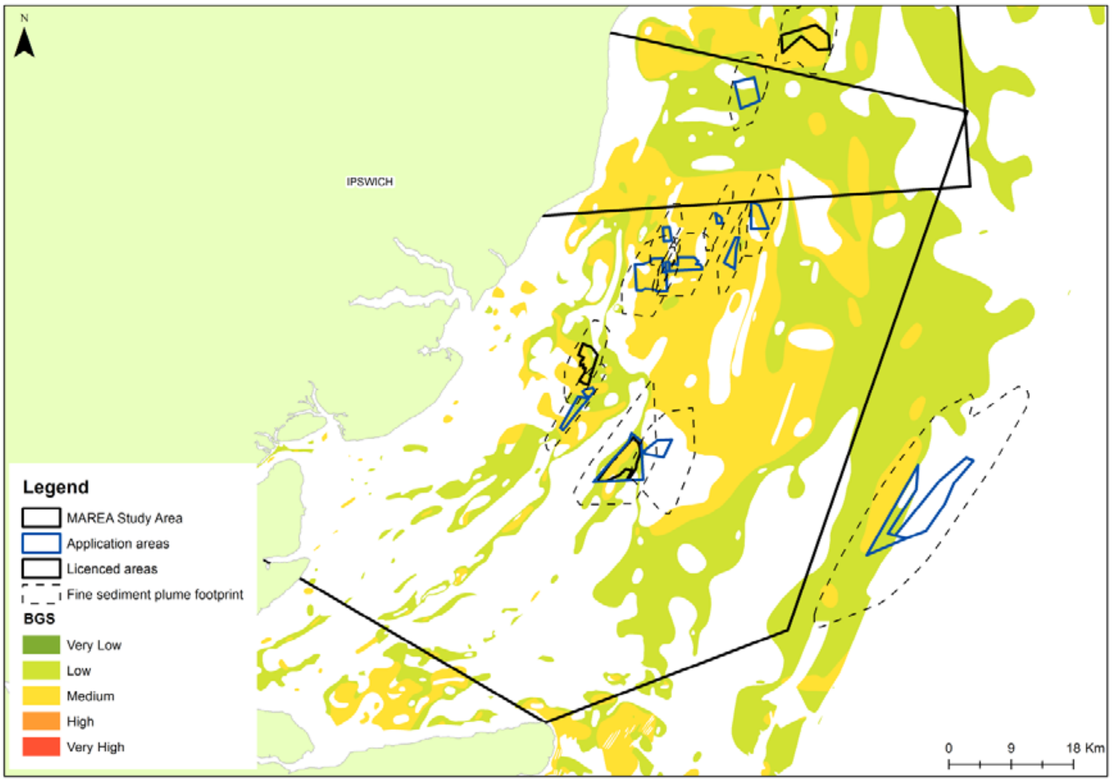


Figure M8: Comparison of the confidence in the Atlantic Herring potential spawning habitat sediment within the Outer Thames Estuary region between the BGS and MAREA data. (Derived from 1:250,000 scale BGS Digital Data under Licence 2013/063 British Geological Survey. ©NERC.; ERM Ltd, 2010)



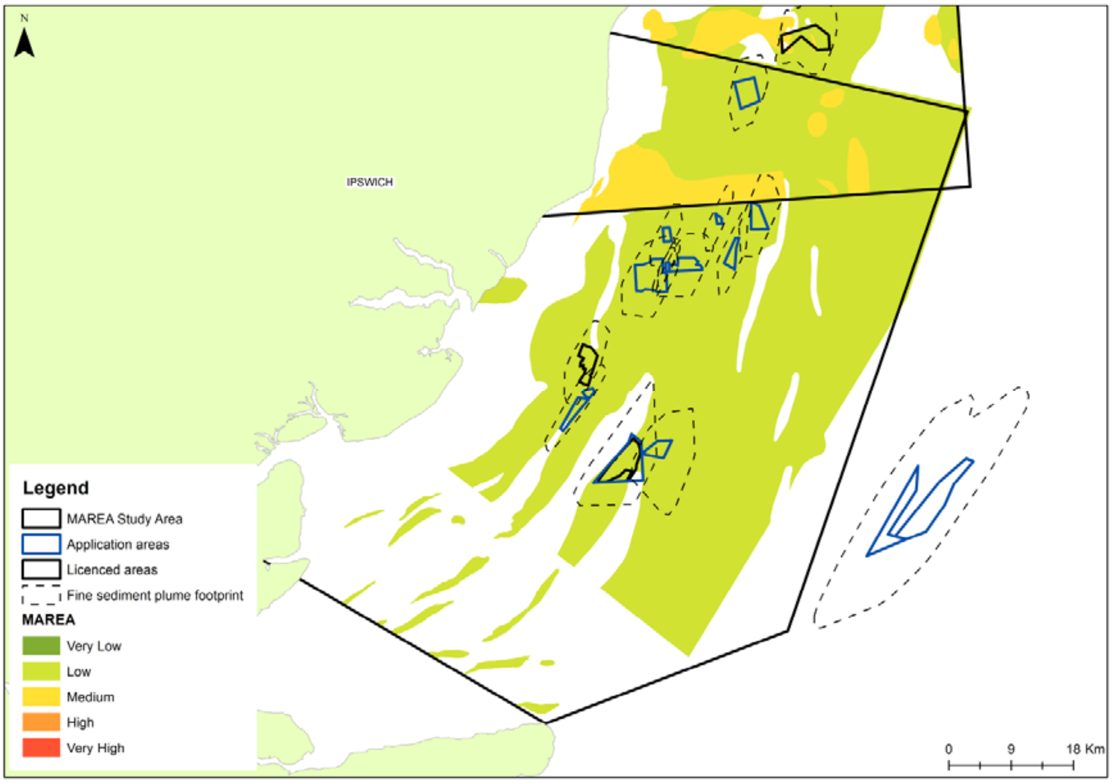
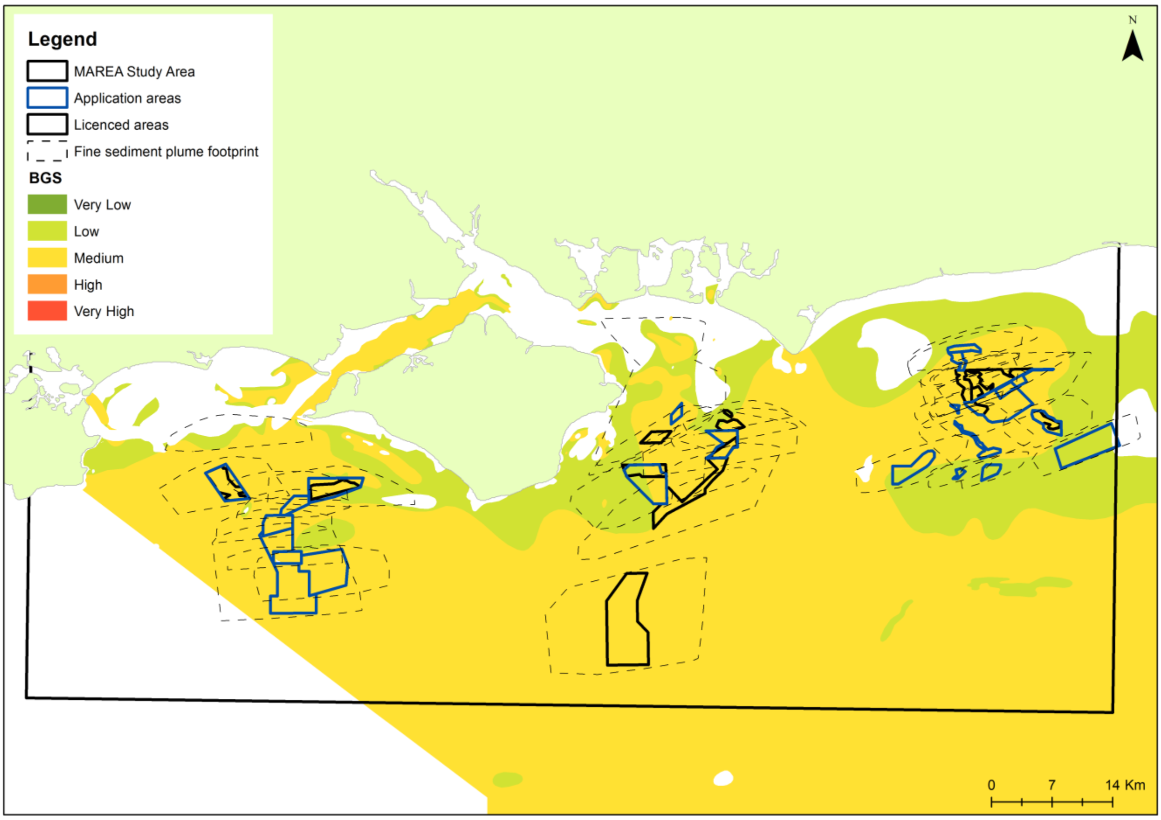


Figure M9: Comparison of the confidence in the Atlantic Herring potential spawning habitat sediment within the Humber region between the BGS and MAREA data. (Derived from 1:250,000 scale BGS Digital Data under Licence 2013/063 British Geological Survey. ©NERC.; EMU Ltd, 2012b)



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