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Identifying and Mapping Atlantic Herring Potential Spawning Habitat: An Updated Method Statement

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

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This updated method statement includes aspects of the methodology described in Reach *et al*. (2013), which is the intellectual property (IP) of the consortium for which MarineSpace Ltd was commissioned to develop the 2013 methodology: MarineSpace Ltd, ABP Marine Environmental Research Ltd, ERM Limited, Fugro EMU Limited, and Marine Ecological Surveys Limited. The aspects of the 2013 (Reach *et al*., 2013) methods, and associated IP, carried over into this updated method statement are explicitly identified within the relevant sections.

Data Licences

GLOSSARY

Abbreviation	Description	Definition
ADZ	Active Dredge Zone	A defined zone 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
CIA	Cumulative Impact Assessment	Process by which the cumulative effects of a plan or project on the environment, and its constituent parts, are determined
	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
DRS	Downs Recruitment Survey	A larvae survey conducted by ICES in the German Bight and Kattegat
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
EEZ	Exclusive Economic Zone	The boundary of UK waters. In this report, the EEZ represents the boundary of the BGS seabed sediment map series
ICES	International Council for the Exploration of the Sea	An intergovernmental marine science organisation that provides evidence on the state and sustainable use of seas and oceans
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 Surveys	The ICES programme of international herring larvae surveys in the North Sea and adjacent areas is in operation since 1967. The main purpose of this programme is to provide quantitative estimates of herring larval abundance, which are used as a relative index of changes of the herring spawning-stock biomass in the assessment
JNCC	The Joint Nature Conservation Committee	The Government's statutory advisor on the marine natural environment from 12 to 200 nm and UK territories

MAREA	Marine Aggregate Regional Environmental Assessment	Assessment of marine aggregate extraction environmental effects at a regional sea scale considering cumulative effects. It is a non-statutory instrument
	Marginal (Habitat)	In the context of this methodology this is the sediment division/unit represented by gravelly Sand which Atlantic herring may use for spawning habitat – see also Suitable (Habitat)
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
	Preferred (Habitat)	In the context of this methodology these are the sediment divisions/units which Atlantic herring favourably select as habitat – see also Prime (Habitat) and Sub-prime (Habitat)
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

	Prime (Habitat)	Atlantic herring spawning habitat which has the ideal sediment structure and supports the greatest densities of spawning activity
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 Cefas, Natural England, JNCC and Historic England
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
SPA	Special Protection Area	These are strictly protected sites classified in accordance with Article 4 of the EC Birds Directive, which came into force in April 1979. They are classified for rare and vulnerable birds (as listed on Annex I of the Directive), and for regularly occurring migratory species

Sub-prime (Habitat)	Atlantic herring spawning habitat with acceptable sediment structure to support some spawning activity
Suitable (Habitat)	In the context of this methodology this is the sediment divisions/units represented by Gravel and sandy Gravel which Atlantic herring may use for spawning habitat. – see also Marginal (Habitat)

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1 Introduction

1.1 Atlantic Herring *Clupea harengus* Linnaeus, 1758

Atlantic herring *Clupea harengus* spawning grounds are understood to have a relatively wide range of seabed habitat and broader environmental requirements and parameters (such as oxygenation of sediments and micro-scale seabed morphological features e.g. ripples and ridges), making fine-scale mapping of these habitats difficult (de Groot, 1979, 1980, 1986, 1996; Bowers 1980; Rankine, 1986; Aneer, 1989; Blaxter, 1990; Morrison *et al.,* 1991; Heath *et al.,* 1997; Maravelias *et al.,* 2000; Maravelias, 2001; Skaret *et al.,* 2003; Geffen, 2009; Greenstreet *et al.,* 2010; Payne, 2010; ECA and RPS Energy, 2010a, 2010b, 2011; Reach *et al.*, 2013; ICES, 2021a, 2021b, 2022).

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, 2021a, 201b, 2022).

Due to the known environmental effects associated with the mechanical removal of sediment surface layers, and the overlap with known Atlantic herring spawning population ranges, it is likely that there are effect-receptor pathways e.g. removal of seabed sediments associated with marine aggregate (minerals) extraction (sands and gravels). Quantification of these pathways and footprints, and assessment of magnitude of effects, will set context and allow environmental assessment for upcoming marine aggregate licence applications, both individually and cumulatively.

1.2 Aims and Objectives

The objectives of this report are to revise and update the previous 2013 heat mapping method described by Reach *et al.* (2013); as used in regional Atlantic herring potential spawning habitat assessment baselines for the UK marine aggregates industry (MarineSpace Ltd *et al.,* 2013; MarineSpace Ltd, 2018a-d). Application of the maps showing potential spawning habitat will allow considerations of environmental effects from marine aggregate extraction activities on Atlantic herring potential spawning habitat, at population- (international/national) and regional-scales.

The analyses and revisions to the 2013 method (Reach *et al*., 2013) have considered the variation in the distribution of Atlantic herring populations in the wider North Sea and The East English Channel (the North Sea Autumnal Spawning (NSAS) populations (see Subsection 2.2.1)) at international/national and regional-scales. The revisions to the 2013 method have resulted in an increase in the scale/extent of seabed that can be assessed in a comparable manner, now extending across the entirety of the central and southern North Sea. This now allows consideration of the full range of potential spawning habitat for relevant NSAS populations to be considered, compared to the 2013 and 2018 assessments, which were focused on seabed habitat within the United Kingdom (UK) Exclusive Economic Zone (EEZ).

In its simplest form, the aim of this report is to describe the processes used to create heat map data-layers. This will allow the screening of all marine aggregate extraction licence areas and application areas against spatial overlap with areas of seabed that have the potential to support Atlantic herring spawning activity. Any licence area or application area that demonstrates a spatial overlap with the seabed area in question will be screened into updated assessments of the environmental effects to inform management of marine aggregate extraction activity within such an area, and at the regional- and spawning population-scale.

There are several seabed user industry activities that are likely to interact with Atlantic herring potential spawning habitat in the UK EEZ, and also across the entirety of the NSAS range, such as:

- Dredge and benthic trawl fisheries;
- Offshore windfarm arrays and export cables;
- Marine aggregate extraction;
- Dredge disposal sites;
- Telecommunications cable routes;
- Interconnector power cable routes;
- Oil and gas supply pipelines.

These activities should be collectively considered as part of a cumulative impact assessment, at a suitable scale, when assessing any possible damage or deterioration to Atlantic herring potential spawning habitat.

To aid the efficient delivery of marine aggregate licence applications under the Marine Works Regulations (as amended 2011) (MWR), and ongoing management advice of existing licence areas, MarineSpace Ltd has been engaged by Boskalis Westminster Limited; Britannia Aggregates Limited; CEMEX UK Marine Limited; DEME Building Materials NV; Hanson Aggregates Marine Limited; Sea Aggregates Limited; Tarmac Marine Limited; and Volker Dredging Limited (collectively referred to as The Operators), to update and revise the original 2013 potential spawning habitat mapping method statement.

This method statement expands on the Reach *et al.* (2013) method that informed the Environmental Impact Assessment (EIA) of marine aggregate extraction activities and associated environmental effects on Atlantic herring potential spawning habitat. In addition, the applicability of the 2013 method informed revised management advice at a North Sea-scale through adaptation of scientific advice by the International Council for the Exploration of the Sea Herring Assessment Working Group (ICES HAWG). Prior to 2015 ICES HAWG advice stated:

"…ICES advises, under precautionary considerations, that activities that have a negative impact on the spawning habitat of herring, such as extraction of marine aggregates and marine construction on the spawning grounds, should not occur".

Following presentation of the Reach *et al.* (2013) method, and associated mapping and Cumulative Impact Assessments (CIAs), to ICES HAWG, the group revised its management advice to:

*"… No activities should be allowed that have negative impact on spawning habitats. Activities that might have a negative impact on the spawning habitat of herring should not occur **unless the effects of these activities have been assessed and shown not to be detrimental**".* – (ICES, 2022)

This advice still stands (ICES, 2022), yet data vintage and accessibility has improved since 2016.

The Reach *et al.* (2013) method was updated in 2018 to incorporate more recent datasets for baseline characterisation of Atlantic herring potential spawning habitat (MarineSpace Ltd, 2018a-d). However, recent statutory and technical advice, and consultation has required variations from the existing Reach *et al.* (2013) methodology. A reassessment of the regional Atlantic herring potential spawning habitat suitability mapping has been agreed through discussions between The Operators and the MMO's Marine Aggregate Regulatory Advisor Group (The RAG)[1]. The fundamental differences between the Reach *et al*. (2013) and the updated method presented here are:

1. The addition of new data-layers and supplementary data-layers, including;
    a. International Herring Larvae Survey (IHLS) (High Abundance) data (indicative data-layers);
        i. The temporal scale of IHLS changed post-2017 and, therefore, data relevant to the Downs population is under-representative post-2017. More information is provided in an explanatory note in Subsection 2.3.5.1, Appendix C, and Appendix D;
    b. OneBenthic Macrofaunal Assemblage data;
2. Integration of both population- and regional-scale mapping;
3. Development of a new heat scoring system enabling future updates of datasets and incorporation of new data-layers whilst maintaining comparability with previous conclusions/assessments.

The metrics, parameters and thresholds describing the environmental characteristics of Atlantic herring potential spawning habitat, presented in this method statement, are intended to generate information of sufficient resolution and confidence to support any assessment of potential spawning habitat for The Operators under the requirements of the MWR process. 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. This methodology can be applied to any area of seabed supported by EMODnet Folk 16 seabed sediment maps[2], 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.

[1] In this case: Cefas, Natural England and Joint Nature Conservation Committee. Historic England are not directly involved as the topic is outside of its statutory remit.

[2] It is recommended that site-specific data can be used to ground-truth the EMODnet data-layer at a Project scale, and evaluated alongside the output heat map during environmental assessment applications.

This methodology update includes aspects of the methodology described in Reach *et al*. (2013), which is the intellectual property (IP) of the consortium for which MarineSpace Ltd was commissioned to develop the 2013 methodology. The aspects of the 2013 (Reach *et al*., 2013) methods, and associated IP, carried over into this updated method statement are explicitly identified within the relevant sections. Significant additions to the original IP are highlighted.

2 Methods

The mapping methodology considers the autecology of Atlantic herring *Clupea harengus* in The Greater North Sea, Waddensea, Skagerrak, and The East English Channel, and potential spawning habitat or ecological and key life-stage indicators i.e. larvae dispersion areas. Validation of mapping appropriate data-layers (including any limitations and confidence) is applied using a structured and tiered method.

The MMO and the RAG has advised the types of effect and effect-receptor pathways that need to be considered as part of the methodology, to satisfy the requirements of the EIA Directive as transposed to the MWR at a meeting held on 01 May 2013 (MMO, 2013), with updated requirements and considerations discussed in a meeting on 16 February 2022 (MMO, 2022).

Any EIA and cumulative impact assessment (CIA) depends upon screening spatial interactions between marine aggregate licence and application areas and habitat having the potential to support spawning activity. *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).

The effect-receptor pathways related to the PIZ that need to be assessed include the direct removal of Atlantic herring potential spawning habitat and eggs, along with physical alteration of the structure of the sediments from direct contact with the draghead. The effect-receptor pathways related to the SIZ include environmental effects from sediment plumes and sediment mobilisation i.e. smothering of *in situ* eggs, and the alteration of potential spawning habitat by fining from settling sands. Therefore, this methodology will enable assessment of both the PIZ and the SIZ footprints.

The MMO and RAG have considered the environmental issues regarding entrainment of adult Atlantic herring and larvae by the dredger draghead and has indicated that entrainment effects are not considered significant in the context of an EIA (MMO, 2013, 2022). Therefore, entrainment effects will not be considered in any marine aggregate area application under the MWR.

It is important to note that the methodology draws upon seabed sediment mapping and 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 preferred benthic habitat, whereas Ellis *et al.* (2012) related the distribution of fish larvae to the ICES sub-rectangles in which they were sampled. Whilst Ellis *et al.* (2012) appears to be beneficial to this methodology compared to the previous 2013 methods (Reach *et al.*, 2013; Latto *et al.*, 2013), it is essentially a duplicate of the Coull *et al.* (1998) and IHLS datasets, and will be rejected by the following data suitability assessment (Section 2.4.1). Therefore, the assessment at population- (international/national) and regional-scales is focussed on the habitat-related data from Coull *et al.* (1998), which supports more meaningful analyses.

It is also important to note that some historic spawning grounds which currently have limited, or no spawning activity can be re-colonised (subsequent seabed recovery from impacts and ability to support spawning activity over time) (Schmidt *et al.*, 2009; ICES, 2021a). 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 applicant's Environmental Statement (ES) regarding requirements to leave the seabed in a pre-dredge state (where possible) at the end of the term of the licence period.

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

The Primary Impact Zone:

- **Direct removal of suitable sediment;**
- **Alteration of habitat structure;**
- **Direct removal of eggs;**
- **Recovery of preferred habitat to support re-colonisation.**

The Secondary Impact Zone:

- **Smothering of *in situ* eggs;**
- **Alteration and recovery of potential spawning habitat by fining**

Previously 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 could also now be linked to the latest review by ICES HAWG, which has assessed the NSAS populations of Atlantic herring as presently being at sustainable levels (ICES, 2021a). Recruitment of larvae and juveniles is still a cause for concern as values have not significantly recovered since 2012 (ICES, 2021a); therefore, the focus of this methodology remains associated with effect pathways on habitat with the potential to support spawning activity (as stated in Reach *et al.*, 2013). Therefore, no consideration will be provided of the effects associated with:

- Sediment plumes on the nektonic/planktonic larvae e.g. fines affecting the feeding of post-yolk sac larvae;
- Any effects resultant at an adult population-scale from receptor-effect pathways listed in the box above (from the PIZ or the SIZ).

The methodology presented in this report uses a tiered approach to map habitat and ecological space and allow assessment of appropriate receptor-exposure pathways: scoping down from Atlantic herring potential spawning habitat at a population-scale (international/national) and an appropriate regional-scale (Figure 2.1). This part of the methodology results in a broadscale preferred and marginal habitat characterisation map (the base map). Preferred and marginal habitats are defined in Table C6 within Appendix C. Fine-scale, licence and application area-specific screening and Cumulative Impact Assessment (CIA) follow, building upon the base map – Stage 3 (Section 2.3; also see Figure 2.5).

It is not envisaged at this time 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 when new data become available.

Figure 2.1: Screening and mapping stages to develop Atlantic herring habitat characterisation

Stage 1 - Population-scale Sediments
EMODnet surface sediment maps

↓

Stage 2 - Regional-scale Sediments
Marine Aggregate Regions and EMODnet surface sediment maps

↓

Stage 3 - Broadscale Habitat Characterisation Base-map

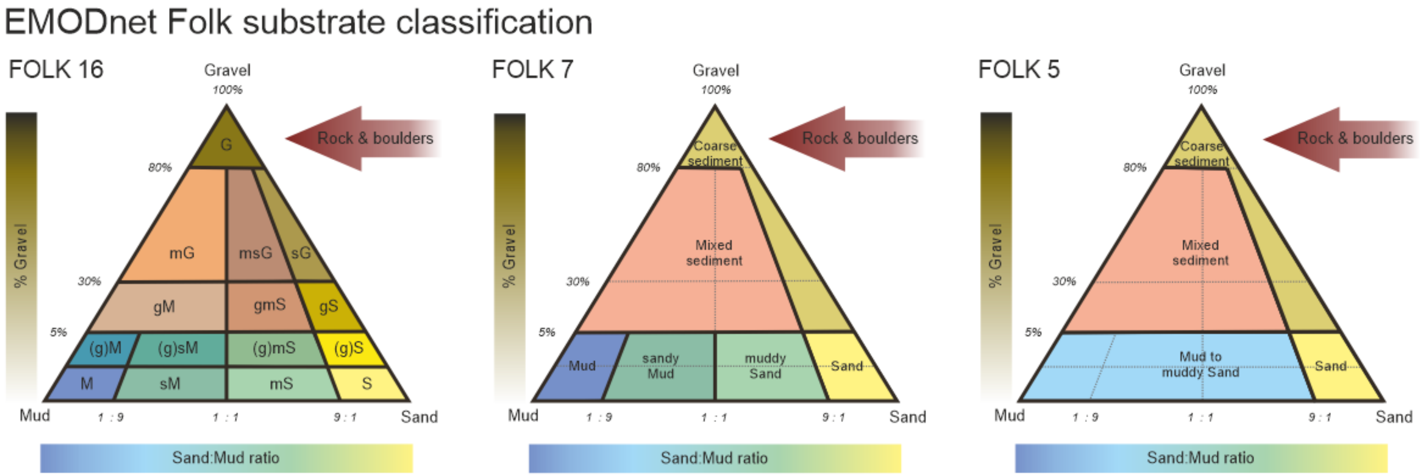
2.1 Review of Seabed Surface Data

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; Maravelias *et al.,* 2000; Maravelias, 2001; Skaret *et al.,* 2003; Geffen, 2009; Payne, 2010; ECA and RPS Energy, 2010a, 2010b, 2011; Reach *et al.*, 2013; ICES, 2021a). In developing the method presented in the Reach *et al.* (2013) report, the project team (MarineSpace and consortium of marine environmental consultancies) reviewed the available data and classifications, liaised closely with fish ecologists and scientists at Cefas, and consulted MMO RAG. Particular attention was 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 of MarineSpace *et al.* (2013) presented relevant extracts of the source material and provided an interpolation of the data using the Folk sediment triangle (Folk, 1954) (see Appendix B of this report).

The Folk classification (Folk, 1954) is used to distinguish between seabed features, and is heavily relied upon by the UK marine aggregate industry for Regional Environmental Characterisation (REC) and Marine Aggregate Regional Environmental Assessment (MAREA) reports. In its most complex form, the classification identifies 15 individual substrate types, and provides the foundation for the BGS 1:250,000 scale seabed sediment map series and has been simplified for use in the BGS 1:1,000,000 scale seabed sediments map series. However, the BGS data-layers do not capture the full extent of the Banks and Downs population distributions as they are limited by the UK EEZ. It is therefore appropriate to examine the suitability of additional seabed sediment composition databases that are not constrained by national boundaries, such as The European Marine Observation and Data Network (EMODnet), for assessing Atlantic herring potential spawning habitat on an international/national scale.

The BGS 1:250,000 scale seabed sediment map series is included in the formation of the EMODnet Folk 16 dataset and has been transformed to project the Folk 16 classification (Figure 2.2). The BGS 1:250,000 scale seabed sediment data within the UK EEZ has not been lost from the methodology but is instead obtained as a subset of the EMODnet seabed substrate 1:250k multiscale dataset. The majority of the North Sea has data coverage, although some areas remain unmapped in French and Norwegian territorial waters. However, these areas are not the focus for regional-scale mapping in this methodology. The use of the EMODnet seabed substrate 1:250k multiscale dataset has therefore been considered appropriate to display Atlantic herring potential preferred and marginal spawning habitat, described in further detail in Section 2.2.1.

Figure 2.2: The Folk classification used by BGS 1:250,000 scale seabed sediments map series, which are incorporated into the UK region of the EMODnet Folk 16 sediment map (From: EMODnet, 2022)



FOLK, 16 classes	FOLK, 7 classes	FOLK, 5 classes
Rock & Boulders	Rock & Boulders	Rock & Boulders
Gravel - G sandy Gravel - sG) gravelly Sand - gS	Coarse sediment	Coarse sediment *(Gravel >= 80% or (Gravel >= 5% and Sand >=90%)*
muddy Gravel - mG muddy sandy Gravel - msG gravelly Mud - gM gravelly muddy Sand - gmS	Mixed sediment	Mixed sediment *(Mud 95-10%; Sand < 90%; Gravel >= 5%)*
(gravelly) Mud - (g)M Mud - M	Mud *(Mud >= 90%; Sand < 10%; Gravel < 5%)*	Mud to muddy Sand *(Mud 100-10%; Sand < 90%; Gravel < 5%)*
(gravelly) sandy Mud – (g)sM sandy Mud - sM	sandy Mud *(Mud 50-90%; Sand 10-50%; Gravel < 5%)*	
(gravelly) muddy Sand – (g)mS muddy Sand - mS	muddy Sand *(Mud 10-50%; Sand 50-90%; Gravel <5%)*	
(gravelly) Sand – (g)S Sand	Sand *(Mud < 10%; Sand >= 90%; Gravel < 5%)*	Sand

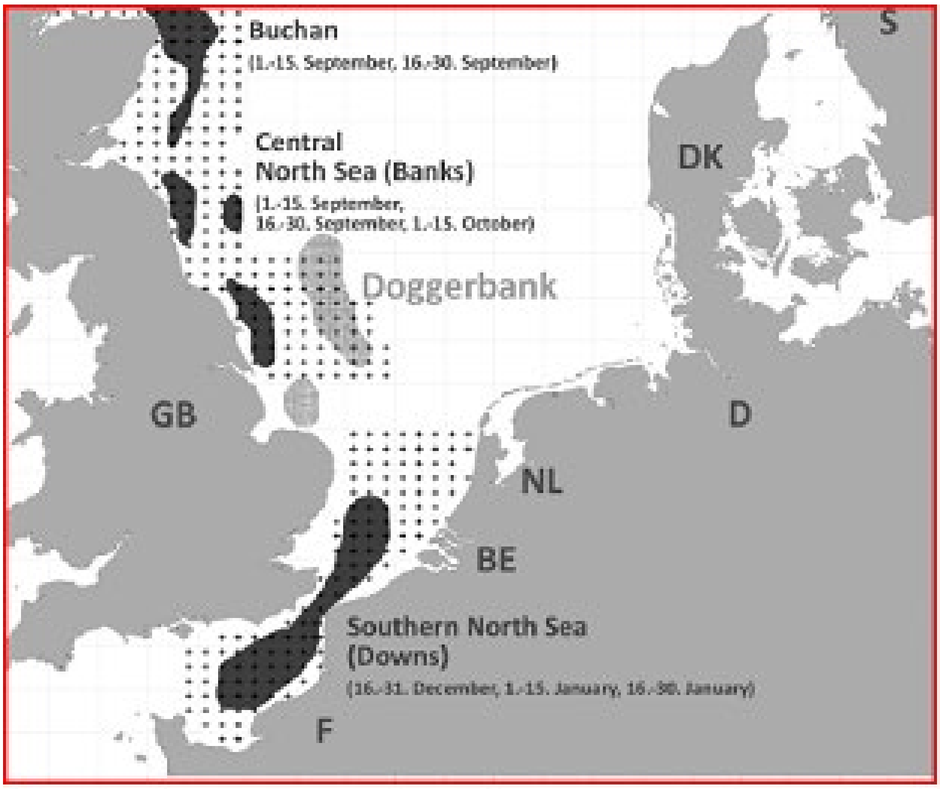
2.2 Stages 1 and 2: Production of the Broadscale Habitat Characterisation Base Maps

This section describes the stages used to create the base map that will provide the foundation layer for consequent heat mapping in Stage 3 of this methodology (Section 2.3).

2.2.1 Stage 1: Population-scale Mapping of Atlantic Herring Distribution

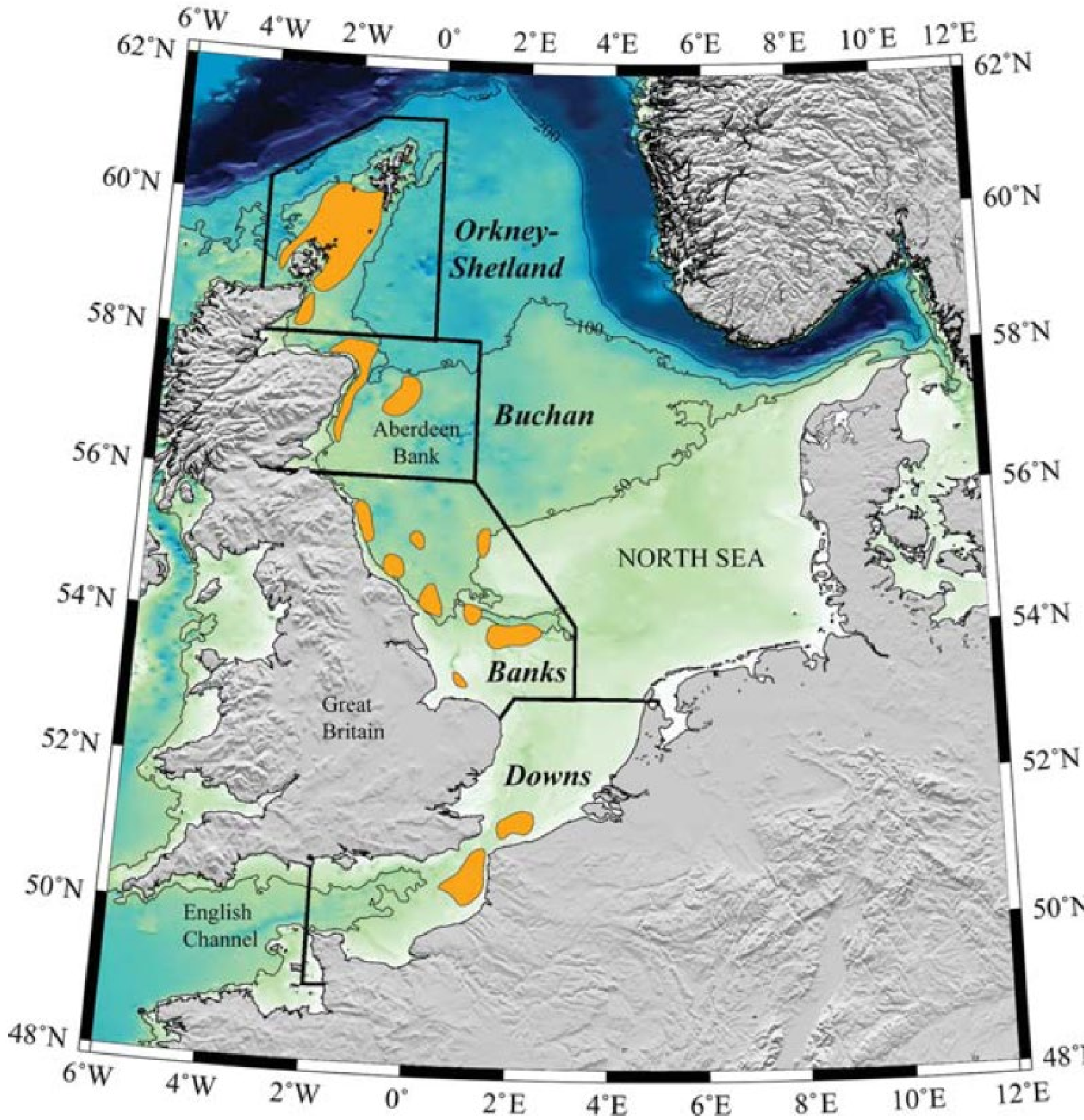
The North Sea Atlantic herring stock is categorised by distinct populations, characterised by the location of their preferred spawning grounds, and more recently by the shape of otoliths and number of vertebrae (Berg *et al.,* 2017). The populations can be split into North Sea Autumnal Spawning (NSAS) or North Sea Spring Spawning (NSSS) populations. Generally, NSAS populations migrate to the Eastern and Southern coasts of the UK (NSAS), whereas NSSS populations remain within Norwegian and Danish coastal waters and the Western Baltic Sea (Dickey-Collas *et al.,* 2010). The primary focus of this method statement is on the NSAS populations, in particular the Banks and Downs populations spanning the Eastern and Southern English coastline (see Figure 2.3 and Figure 2.4).

Figure 2.3: Distribution of Atlantic Herring spawning populations recorded in UK Waters. (From: Schmidt *et al.*, 2009)



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

Figure 2.4: Distribution of Atlantic Herring spawning populations recorded in UK Waters. (From: Payne, 2010)



The international/national distribution of Atlantic herring populations is an important consideration in the context of fisheries stock assessment. Due to the pelagic nature of Atlantic herring, there is potential for mixing between NSAS and NSSS populations in the North Sea, that is likely related to the mixing at regional spawning grounds. Spawning stock biomass (SSB) calculations cannot distinguish spawning stocks, and therefore the extent of potential spawning habitat should be included at this stage. Table 2.1 summarises the most recent North Sea Atlantic herring stock data for ICES Divisions 4a-c, 3a, and 7d, that characterises the NSAS stock spawning in The Greater North Sea (ICES Subarea 4, Divisions 4a-c), Skagerrak (ICES Subarea 3, Division 3a), and The East English Channel (ICES Subarea 7, Division 7d) (ICES, 2021a; ICES, 2021b). For reference, the relative spatial extents of ICES Subareas and Divisions are located in Appendix A.

The total area required for spawning in ICES Divisions 4a-c, 3a, and 7d assumes:

- Average mature fish (3+ ringers – based on >98% maturity in 3+ classes) of 0.255 kg;
- One male spawner per female spawner;
- An egg carrying capacity of 20,000-50,000 eggs per female;
- An egg density on the seabed of 750,000-2,500,000 eggs per m^2.

Table 2.1: North Sea Atlantic herring stock data for ICES Divisions 4a-c, 3a, and 7d (ICES, 2021a; ICES, 2021b)

Average Weight per Adult Fish (kg)	Density of Females (no. per m^2)	SSB (kg)	Total Area Required for Spawning in ICES Divisions 4a-c, 3a and 7d (km^2)
0.255	15-125	1,383,486	22-183

The location of NSAS potential spawning grounds within the North Sea will be mapped using EMODnet Folk 16 substrate data (as identified above), in relation to the wider Atlantic herring North Sea stock (including the NSSS populations with fidelity to Norwegian fjords and coastlines, Skagerrak, and Kattegat). This will characterise the distribution of spawning populations within the entirety of the North Sea and provide context for the regional-scale mapping of NSAS populations in Stage 2 of the methodology.

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 (Banks) and Southern North Sea (Downs) 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.

2.2.2 Stage 2: Regional-scale Mapping of Atlantic Herring Preferred and Marginal Habitats Within Marine Aggregate Strategic Areas

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 Atlantic 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; Maravelias *et al.,* 2000; Morrison *et al.,* 1991; Maravelias, 2001; 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 spawning NSAS 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 2.5).

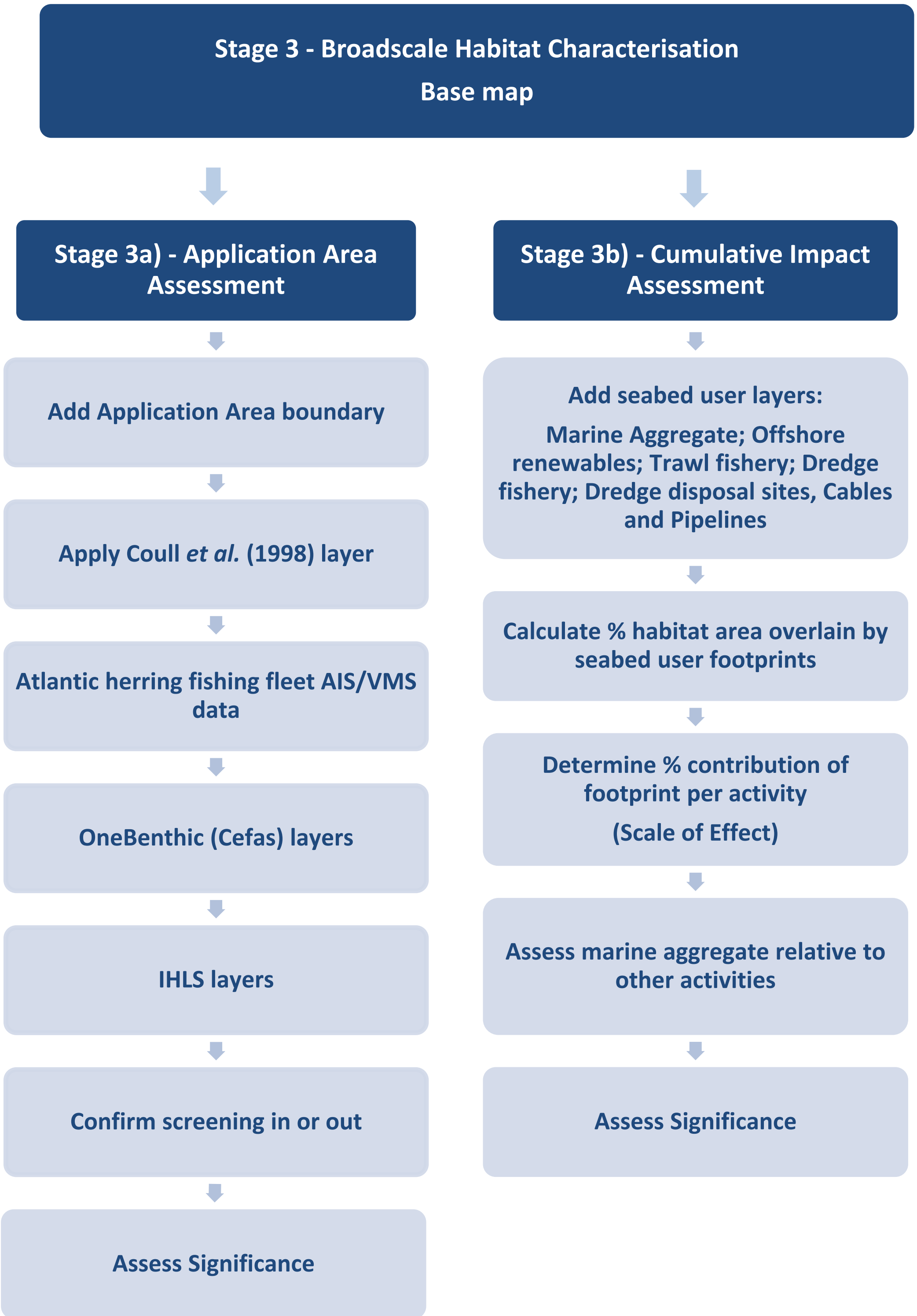
Stage 2 of the method uses the EMODnet Folk 16 substrate data, which incorporates BGS 1:250,000 data used in MarineSpace Ltd (2013) as identified above, to map the habitat with the potential to support Atlantic herring spawning at a regional-scale. The regional extent of the habitat can be identified and calculated, regarding the specific licence and application areas and the associated impact zones. This value will subsequently be used when calculating the level of interaction between application/licence areas, either alone or cumulatively, and the habitat receptor.

A detailed regional-scale consideration of potential habitat using REC/MAREA maps could be made, but care must be taken when comparing to the base maps as REC/MAREA data have increasing vintage, are site-specific, and are not linearly proportionate to wider spatial areas. In addition, the EMODnet data-layer contains information from REC datasets, and therefore the inclusion of RECs would result in the duplication of data. For these reasons, and the spatial extent of the updated EMODnet data-layer, unlike the 2013 methodology, no further consideration of REC/MAREA data will be made within this assessment.

No longer using the REC/MAREA seabed sediment data is a deviation from the original 2013 method (Reach *et al.*, 2013). However, it should be noted that an updated MAREA process is likely to start during 2024, and if any new regional-scale data are acquired as part of that process, those data could be incorporated into this revised method in the future.

Stages 1 and 2 thus provide the Broadscale Habitat Characterisation Layers (base maps). A calculation of preferred and marginal habitat can be conducted at this stage for Atlantic herring, although the methodology also applies to sandeel species. All sediments which fall outside the specified classifications for each species group do not need to be considered further for their relevant heat mapping. This regional extent can subsequently be related as a percentage of the total habitat available at the international/national scale (as identified in Stage 1). This value, along with the base-map, can be used to inform both the individual licence or application and CIAs at Stages 3a) and b) respectively, through parallel processes (Figure 2.5).

Figure 2.5: Screening levels to enable marine aggregate licence area-specific, and cumulative impact assessments with Atlantic herring preferred and marginal spawning habitat



2.3 Stage 3: Refined Heat Maps for Atlantic Herring Potential Spawning Habitat

Once the base maps have been created, additional data-layers can be overlaid to improve confidence in determining the spatial extent of Atlantic herring potential spawning grounds in relation to proposed, new and existing licence areas. Data are obtained from a variety of sources including primary literature and survey studies and ranked in terms of confidence in the data-layer's representation of spawning grounds.

It is at this stage that the 2013 methodology (Reach *et al.*, 2013) becomes integrated with the updated method. Subsections 2.3.1-2.3.3 have been sourced from the 2013 methodology (Reach *et al.*, 2013), and updated to include the most recent data available. Subsection 2.3.5 has been partly sourced from the 2013 methodology (Reach *et al.*, 2013), but updated to reflect changes in effort within the IHLS survey method . Subsection 2.3.4 is a new data-layer for the updated methodology. Subsections 2.3.6 and 2.3.7 are sourced from the 2013 methodology (Reach *et al*, 2013).

2.3.1 Stage 3a)i: Licence Area and Application Area Boundaries for the Primary Impact Zone (PIZ) and the Secondary Impact Zone (SIZ)

The first layer under the assessment approach (Figure 2.5) is to map the licence/application area boundaries and indicative SIZs. The methodology assumes that the boundary of the licence/application area is representative of the potential total PIZ i.e. an active dredge zone (ADZ) may occur anywhere within the licence/application boundary during the period of the term applied for (15 years). The SIZ footprint is to be sourced from the ES of each licence/application area, 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 Stage 3a) is intended to allow separate pressures to be assessed at a licence-specific scale e.g. application area boundary (PIZ) is the potential area for habitat or egg removal; SIZ and sediment plume footprint is the potential egg smothering zone and area for habitat loss/alteration through sediment fining (the addition of fine sands that backfill sediment interstices, 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 licence or application areas or SIZs are screened out at this stage. This is due to the potential for exposure pathways within licence/application area PIZs and SIZs that do not constitute preferred or marginal habitat, such as larval drift, that will be indicated by other data-layers. This enables a degree of conservatism to be incorporated into the methodology and ensures all possible exposure pathways are considered before the final screening at the end of Stage 3a).

2.3.2 Stage 3a)ii: Known Atlantic Herring Spawning Grounds (Coull *et al*, 1998)

This data-layer draws upon the spawning ground assessment conducted by Coull *et al.* (1998). See Section 2, page 2-1 for an explanation of the reasons why Coull *et al.* (1998) is considered more relevant for this method statement than the more recent assessment conducted by Ellis *et al.* (2012).

The Coull *et al.* (1998) data-layer is mapped, and any overlap with licence area boundaries (and associated SIZs) are identified. 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 re-analyse the data), licence and application areas that fall outside the envelope are still progressed to the next stage of screening.

2.3.3 Stage 3a)iii: Fishing Fleet Automatic Identification System (AIS)/Vessel Monitoring System (VMS) Database

Given the uncertainty (low confidence) of the Coull *et al.* (1998) data-layer describing the full extent of Atlantic herring potential spawning areas, the spatial layer should be enhanced where possible. The revised 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 Stage 3a)ii 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 RAG (MMO, 2013, 2022).

2.3.4 Stage 3a)iv: OneBenthic (Cefas) Database

Stages 3a)i – iii are broadly similar to the Reach *et al.* (2013) methodology used in the MarineSpace Ltd *et al.* (2013) and MarineSpace Ltd (2018a-d) reports. However, recent advances in data availability (and crucially their accessibility) have been made that could provide more insight to the location and spatial extent of Atlantic herring potential spawning grounds. The OneBenthic database (developed by Cefas) is a collection of tools that collate biological and geophysical information from a variety of sources and allow datasets to be freely analysed and extracted.

Consideration of use of data accessible from the OneBenthic Database is an addition to the previous 2013 method statement (Reach *et al.*, 2013).

Whilst currently in a developmental phase, OneBenthic could provide a ‘one-stop-shop’ for baseline data used in assessments for all marine development projects, and thus increase the level of data transferability between each sector e.g. marine aggregates, renewables, and oil and gas. In time, a holistic picture of the distribution of seabed features, sediments and habitats will be created and added to future method updates. Incorporating similar methods to the one outlined in this statement will improve confidence in the location and spatial extent of ecologically important features, sediments, and habitats, to better inform environmental impact assessments for marine development projects.

In this revised method, the OneBenthic Macrofaunal Assemblage dataset, extracted from the OneBenthic Data Extraction Tools (refer to Appendix C), will be incorporated into the heat mapping process as an indicator of sediment class, due to the relatively limited variability in preferred habitat for each macrofaunal assemblage. These assemblages essentially act as sentinel species (Serrano *et al.*, 2022), that can be used to both identify specific sediment type and assess the condition of the seabed for long-term monitoring studies within licensed areas.

Datasets exported from OneBenthic currently have high sampling intensity but limited spatial extent on a regional-scale, and care must be taken when comparing against other data-layers such as the EMODnet Folk 16 base map. As time progresses, this data-layer has the potential to become relevant to the wider seabed sediment composition and distribution, at which point it could carry greater confidence than EMODnet seabed substrate maps. However, it is not intended that this data-layer will replace the EMODnet seabed substrate maps.

2.3.5 Stage 3a)v: International Herring Larvae Survey (IHLS)

The final pre-screening 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 Survey (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).

2.3.5.1 Explanatory Note

It is important to note that the temporal scale of the IHLS methodology has changed since 2017, due to a shift in survey effort away from the Downs spawning population, specifically the discontinuation of the third IHLS survey (16-31 January) (Louise Straker Cox, Cefas, pers. comm.). Whilst ICES undertakes the Downs Recruitment Survey (DRS) within the German Bight and Kattegat, the DRS utilises alternative methods to the IHLS and does not distinguish natal spawning locations for larvae sampled within the DRS. Therefore, the DRS cannot be compared to IHLS data or used to inform the output heat map (Louise Straker Cox, Cefas, pers. comm.), and has not been considered further in this methodology.

In addition, there is limited IHLS data coverage for parts of the central and southern North Sea Atlantic herring populations within UK Territorial Waters. However, the IHLS protocol used to sample the seabed for Atlantic herring larvae has not changed and, therefore, the pre-2017 (data collected between 2002 and 2017) and post-2017 data remain comparable and appropriate for subsequent assessment applications of the methodology of the IHLS (General) data-layer. Care should be taken, however, when assessing IHLS data at a population scale, as the Downs spawning population will be under-represented in all post-2017 IHLS data. Further detail on pre-2017 and post-2017 is provided in Appendix D.

2.3.5.2 IHLS (General) Data

The 'IHLS (General)' data-layer is used to enhance the information used in Stages 3a)ii and iii, and is mapped over the preceding layers. These spatial data will be used to filter and refine the spatial extent of potential spawning habitat. Comparing the available Atlantic herring larvae distribution data against the Atlantic herring potential spawning sediments identified in Stages 1 and 2 increases the confidence in identifying areas of seabed which are known to have not only Atlantic herring present, but also the potential habitat.

As explained in Section 2.3.5.1 (and Appendix D), the IHLS sampling of the Downs spawning population is under-representative of the spawning activity within the Anglian, Outer Thames, East English Channel, and South Coast Regions. Despite this underrepresentation, the IHLS (General) data-layer retains the maximum spatial extent of IHLS sampling stations containing larvae within both pre-and post-2017 data; providing a contextual baseline of known spawning grounds for both the Banks and the Downs spawning populations and maintaining comparability with conclusions made within assessments that used the 2013 (Reach *et al.*, 2013) methodology.

2.3.5.3 IHLS (High Abundance) Indicative Data

Due to low predictability of spawning locations between years, abundance data is a useful metric to obtain from IHLS data; which can be used to understand the variation in potential 'hotspots' of high intensity Atlantic herring spawning activity, indicated by a greater density of 0-ringer larvae. Therefore, separate from the IHLS (General) data-layer, IHLS data will be categorised into 3 polygons per 'IHLS (High Abundance)' data-layer, that can be utilised alongside the heatmap (without contributing to the identification of heat directly). These polygons will include:

- Sample stations with 51-200 larvae per m² = medium density[3];
- Sample stations with 201-600 larvae per m² = high density;
- Sample stations with >600 larvae per m² = very high density.

Due to the use of the IHLS (General) data-layer indicating 0-ringer larvae at any density and, therefore, having a very large spatial scale, the IHLS (High Abundance) data-layers characterise 'hotspots' by limiting the dataset to the highest density classes. High larval density (>51 larvae per m²) collected at an IHLS station have been determined as indicative of (high-level) potentially important spawning grounds, with the IHLS (General) data-layer being a similar, but more relevant, data-layer to the potentially important spawning grounds identified by Coull *et al.* (1998).

[3] It is noted that sample stations with <51 larvae per m² are considered to indicate areas of low spawning intensity, and have, following consultation with Cefas, been excluded from the IHLS (High Abundance) data-layers. High abundances, when related to seabed coverage (per m²), are considered to indicate areas of medium-very high densities of larvae, indicative of 'hotspots' of spawning activity as related by the 3 density classes.

As Atlantic herring do not show exact spawning site fidelity between years, a time series of IHLS (High Abundance) data-layers should be used to identify areas with the greatest importance for spawning activity in the years preceding the assessment. Therefore, a minimum 10 year period of IHLS (High Abundance) data-layers has been deemed appropriate to show variation between important areas of spawning activity, to aid subsequent assessments. However, for the Downs spawning population, post-2017 IHLS data may under-represent peak spawning activity and peak larval abundance (see Appendix D). Therefore, IHLS (High Abundance) data-layers from 2007-2017 will also be provided as a 10 year baseline (see Appendix C), to aid subsequent assessment applications of the methodology, and to identify potential under-representation of larvae abundance for the Downs spawning population (see Appendix C). This pre-2017 baseline dataset will be retained for use alongside a minimum 10 year period of post-2017 data. It is noted that current (<10 year period) post-2017 data remain relevant for use in associated assessments.

It should be noted that the IHLS (General) and IHLS (High Abundance) data-layers show different information and, therefore, should not be directly compared. In addition, greater resolution will be given compared to the heat map by indicating areas of high density 0-ringer larvae and, therefore, indicate intensive potential spawning activity for Atlantic herring.

2.3.6 Stage 3a)vi: Confirm Screening In or Out

Spatial overlap between a licence area, the SIZ footprint and the data-layers described above will be used to screen licence and 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 licence/application area (or associated SIZ) and more than one of the data-layers from Stages 3a)i-v. Sediment habitat layers (the base map, Stages 1 and 2) and IHLS and plan/project-specific larvae data-layers (Stage 3a)iv) will possess the highest confidence (and weight). Descending confidence will be ascribed to OneBenthic data, 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 data-layers. Licence and 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, as a precautionary approach.

Licence or application areas with no spatial overlap with any of the data-layers described in Stages3a)i-v above will be screened out of further assessment. They will forgo an EIA for Atlantic herring preferred or marginal habitat as it is demonstrated that there is no receptor-exposure pathway. For any licence or application area not screened out then the resolution from Stage 3a)iv is intended to allow licence or application area-scale effects to be considered; where the licence or application area boundary is considered to = PIZ = potential area for habitat removal.

2.3.7 Stage 3b: Cumulative Impact Assessment

The CIA process allows a characterisation of the seabed footprint of relevant seabed activities (Figure 2.5). This stage 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 Stage 1 and used in Stage 3. The percentage of area of habitat overlap and scales of effect (percentage of contribution per activity) at a regional-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 Stage 3a)i such that it is assumed that the boundary of the licence/application area is representative of the potential PIZ i.e. an active dredge zone (ADZ) may occur anywhere within the licence or application area 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 CIA will consider the footprint of all the appropriate seabed user activities at a regional-scale. The boundary of the regional-scale CIA will be the same as that indicated and mapped at Stage 2 of this methodology. The relevant seabed user activities identified as interacting with Atlantic herring potential preferred and/or marginal spawning habitat are listed in Table 2.2 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 to 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.

Through use of the new/updated Stage 1 population-scale seabed sediment mapping layer, it may now be possible for a population-scale CIA to be conducted, considering anthropogenic effects on potential spawning habitat across the range of the NSAS spawning populations. This may be more appropriate for the Downs population, which is known to spawn through the central North Sea, outer Thames estuary, east English Channel, and across the southern North Sea as far as the Waddensea. The Banks population’s spawning areas are predominantly located within the UK EEZ, from northeast Scotland southwards along the English north coast to the Humber Estuary (Figure 2.4).

Table 2.2: Seabed user activities likely to interact with Atlantic herring preferred and marginal spawning habitat at a regional-scale

Seabed User Activity	Data
Marine aggregate licence areas	Licence/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 disposal sites	Cefas data with plume footprints where known

2.4 Confidence Assessments

The confidence assessment methodology has been sourced from the 2013 methodology (Reach *et al.*, 2013), and only updated to reflect changes in the data-layer inputs as part of the revised methodology update. The final confidence scoring system is new for the updated methodology; however, the main structure of the individual data-layer confidence assessment and the confidence scoring method itself is unchanged from the 2013 methodology (Reach *et al.*, 2013). This allows comparison between the 2013 methodology and the updated methodology.

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

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

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

An overview of the confidence assessment process is presented here, using the Reach *et al*. (2013) report as an example; however, the detailed Confidence Assessment Protocol is presented in Appendix C and informs a thorough understanding of the rationale and methods used within this study. The rationale and methodology used in Confidence Assessment Protocol was originally used in the 2013 methodology (Reach *et al.*, 2013), based upon an MMO methodology, and has been deemed appropriate for use (at a meeting held on 16 February 2022 (MMO, 2022)).

It is important to note at this stage that the EMODnet dataset has a different confidence score for Atlantic herring than when used for mapping potential supporting habitat for sandeel (see Reach *et al*., 2024).

2.4.1 Data Considered

The spatial datasets considered in the confidence assessment to inform the location of Atlantic herring potential spawning grounds will include the layers presented in Stages 1-3 in Sections 2.2-2.3:

- Substrate Folk Classification: European Marine Observation and Data Network (EMODnet);
- Substrate Folk Classification: OneBenthic Macrofaunal Assemblage data;
- Fishing Fleet: Vessel Monitoring Systems (VMS);
- Fishing Grounds: Eastern Sea Fisheries Joint Committee (ESFJC);
- Spawning Grounds: Coull *et al.* (1998);
- Spawning Grounds: International Herring Larvae Surveys (IHLS) (General);
- Spawning Grounds: IHLS (High Abundance) (51-200 larvae/m^2);
- Spawning Grounds: IHLS (High Abundance) (201-600 larvae/m^2);
- Spawning Grounds: IHLS (High Abundance) (>600 larvae/m^2).

All data are required in a polygon format (area of spatial extent), as opposed to point, line, or raster/gridded data as this allows them to be combined and result in an overall assessment. Data will be omitted following an assessment of suitability. For example, multiple datasets may show similar data (duplicates) or may be missing data that would reduce the validity of the heat map.

2.4.2 Confidence Test Method

The scoring proforma developed for the Reach *et al*. (2013) and Latto *et al*. (2013) reports applied confidence assessments as shown below (Table 2.3). The scoring proforma was adopted where there were no supporting spatial data to inform spatial variation in confidence.

The first 5 parameters (method, vintage, positioning, coverage, quality standards) are concerned with the data, i.e. how confident is the mapper in the data being as described, whether this is seabed sediment, known spawning grounds, or fishing activity?

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

Table 2.3: Data parameters and weighting used in the Confidence Assessment Protocol and Methodology (From: Reach *et al*., 2013; Latto *et al*., 2013)

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

The final parameter, ‘indicator of spawning’, is not concerned with the data themselves, but the confidence in the data indicating potential 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 potential spawning grounds? As this methodology uses 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 the development of this methodology. A value of 5 results in this parameter holding the same weight as all the preceding 5 parameters combined.

All datasets are assessed in order to consider whether any supplied parameters could be used to inform spatial variation in confidence, whether applied to confidence in the data themselves or confidence in the indication of spawning grounds. This assessment is 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 previously approved by Cefas regarding the datasets used in the 2013 methodology (Reach *et al.*, 2013; Latto *et al*., 2013) and the MarineSpace Ltd *et al*. (2013) report. For the IHLS (High Abundance) data, abundance has been used to determine areas of potential high-intensity spawning activity. Further information regarding the use of the IHLS (High Abundance) data-layers can be found in Appendix C.

It was concluded in the 2013 methodology (Reach *et al.*, 2013; Latto *et al*., 2013) and the MarineSpace Ltd *et al*. (2013) report that only 2 datasets had spatial variations in a parameter that informs confidence: seabed sediment Folk class for each of the BGS and MAREA datasets; which in this method statement translates to the seabed sediment Folk class for the EMODnet dataset, following the exclusion of the MAREA dataset from this methodology.

2.4.3 Scoring

For each parameter or confidence test shown, a score between 0 and 3 is assigned, where 0 = unknown and 3 = high confidence (Table 2.4). However, for the 'indicator of spawning' (final parameter in Table 2.3), a score of 0 would mean it is unknown whether the dataset can be used to infer spawning locations. This is not applicable for this parameter, as if this were the case the layer should not be included in the project. Therefore, a score of 0 for 'indicator of spawning' = very low confidence.

Table 2.4: 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, normalising to a range of 0-5 as per the 2013 methodology (Reach *et al.*, 2013), and then converting to the updated decimal scoring system (see Appendix C for detail).

2.4.4 Confidence in the Seabed Habitat Sediments Data as an Indicator of Potential Spawning Habitat

As detailed in Reach *et al.* (2013), Atlantic herring is known to prefer Gravel and sandy Gravel seabed sediments; and have a marginal habitat sediment class of gravelly Sand. Therefore, the Folk sediment classification provides a spatially variable indicator to spawning and hence the level of confidence is also variable (see Subsection 2.2.1; Appendix B).

The level of confidence in Folk classes indicating Atlantic herring 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 B; Reach *et al.*, 2013). This field is termed 'Folk category indicates marginal/preferred habitat' and is represented by the Y-axis in the matrix below (Table 2.5).

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 Atlantic herring 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 which 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' (Table 2.5).

Normally, such matrices are provided for parameters scored from low to high, or numerically, 1-3. However, in this case, it is never possible that the EMODnet data can indicate Atlantic herring potential 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-layer. Therefore, the matrix is scored from 0-2 (Table 2.5). As detailed in Section 2.4.3 above, where scoring the indicator for spawning, a zero score does not imply 'unknown', but 'very low' instead.

Of the 3 Folk categories that represent Atlantic herring potential spawning habitat sediment class (Gravel (G), sandy Gravel (sG), and gravelly Sand (gS)), all over-represent the habitat divisions due to the percentage of unfavourable mud within each class (see Appendix B for detail). This reduces the confidence in the EMODnet data-layer indicated by the Atlantic Herring Matrix results (Table 2.6).

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

Table 2.5: General Matrix - Each of the two parameters is scored separately from 0 to 2 (very low to medium); then the two are combined as shown

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

Table 2.6: Atlantic Herring Matrix – Application of the General Matrix to the EMODnet Folk sediment classes

Atlantic Herring Matrix	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

2.4.5 Confidence in the International Herring Larvae Survey Data Indicating Potential Spawning Habitat

The IHLS data will have the highest confidence (score of 3) as they are 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 in the IHLS (General) data-layer is related to the standard/credibility of the data, not the scale of spawning. Therefore 0 = absence and ≥1 = present, for that data-layer. However, these count data will not be lost in the assessment process, i.e. number count will still be used to inform any EIA/CIA through the inclusion of the indicative IHLS (High Abundance) data-layers within any assessment (see Appendix C for detail).

In the 2013 methodology (Reach *et al.*, 2013) and the MarineSpace Ltd *et al*. (2013) report, the equivalent of the IHLS (General) data-layer was afforded the highest confidence possible due to its direct sampling of Atlantic herring spawning grounds. Whilst the 2018 update to the methodology (MarineSpace Ltd, 2018a-d) incorporated pre-2017 IHLS data, the methodology in which ICES collects data for the IHLS has since changed (see Appendix D). Post-2017 data does not include the late-January IHLS survey present within pre-2017 data, and therefore does not fully represent the Downs spawning population within the Anglian, Outer Thames, East English Channel, and South Coast Regions (see Appendix D). However, the remaining IHLS surveys are collected using pre-2017 survey protocols and, therefore, the post-2017 IHLS data remain comparable to the pre-2017 IHLS data. As such, the IHLS (General) data-layer contains a 2002-present time series for both the Banks and Downs populations, represented by the Humber, Anglian, Outer Thames, East English Channel, and South Coast Regions. Refer to Section 2.3.5.1 of the methodology report, and Section C2.6 of Appendix C, for further information.

Survey effort has improved since the original 2013 methods, and the pre-2017 IHLS data remain the same as those used in MarineSpace Ltd (2018a-d). There are still areas of poor coverage at inshore locations, particularly around the northeast coast of Norfolk and the Outer Thames inshore area (northwest of the marine aggregate Outer Thames Region). However, the spatial coverage of marine aggregate regions is comprehensive and reliable.

2.4.6 Confidence in the Combined Data

As an example, Table 2.7 below shows the results of each of the confidence assessments per layer plus the final single layer confidence score from the MarineSpace Ltd *et al*. (2013) report. The expected scoring for the latest data-layers as discussed in Section 2.3 of this method statement are outlined in Appendix C.

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

Each individual layer is first scored on five parameters or tests relating to the data themselves: each of these tests result in a score of 0-3 (Section 2.4.4, Table 2.4, and Appendix C). These scores are then summed for each individual layer and then normalised back to a range of 0-3 (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 spawning habitat.

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

The total weighted score then combines all the parameter scores together. The parameter scores for confidence in the data are added to the weighted indicator score which is weighted through multiplication by 5. By multiplying by 5, the indicator score has equal weight to all the other 5 scores combined. The total weighted score for a given layer can therefore range from 0-30 (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 Score' for Atlantic herring is then calculated by normalising the total weighted score for Atlantic herring to a range of 0-5 (i.e. by dividing by the total possible score of 30 and multiplying by the range, 5). Whilst these values could have ranged 0-3 as with the rest of the scores, this did not allow enough variation between the datasets. A range of 5 was originally considered in the 2013 methodology (Reach *et al*., 2013) to show a suitable level of variation (very low = 1.00, low = 2.00, medium = 3.00, high = 4.00, and very high = 5.00).

The following indicates a significant deviation from, and update to, the original 2013 method statement (Reach *et al.*, 2013).

The updated scoring system converts these 'Total Normalised Scores' to decimal values within a range of 0.90-0.10. These individual data-layer values, presented as 'New Total Normalised' in red text in Table 2.7, were assigned to each shapefile attribute table ready to contribute towards the final combined confidence mapping layers.

The addition of new data-layers using the 2013 scoring system (Reach *et al*., 2013) would reduce the relative confidence of existing data-layers in the heat mapping process. The conversion to a range of (very low = 0.90, low = 0.75, medium = 0.50, high = 0.25, very high = 0.10), and the multiplication of individual layers provides the heat score without reducing relative confidence. By converting the Total Normalised Scores, the heat score value exponentially decreases where layers overlap, but for areas where a new data-layer is deficient (i.e. no additional overlap with existing layers), the relative heat score of data-layers is retained.

For example, using data-layers identified in the 2018 updated version of the 2013 methodology (Reach *et al*., 2013), each heat group would consist of four intervals (1.00-4.00 = low; 5.00-8.00 = medium; 9.00-12.00 = high; and 13.00-16.00 = very high). The addition of the OneBenthic Macrofaunal Assemblage data as part of the updated methodology (but still using the 2013 scoring system) would have increased the maximum value from 16.00 to 20.00. Therefore, to retain 4 heat groups (low to very high), the number of intervals per group would have to increase from 4 to 5. This violates the rule that the maximum individual layer score (5.00) cannot be represented by the lowest heat category.

To retain this rule, the number of heat groups must increase, which increases the complexity and reduces usability of the final heat map output, in addition to reducing the relative score of individual layers. As such, this updated methodology will not classify heat scores within the final output's scale. More detail is provided in Section 2.4.9 and Section 2.5.

Using the new, revised method, contrary to the 2013 methodology (Reach *et al*., 2013), all scores within the confidence assessment with a low number now reflect high confidence in the data indicating potential spawning habitat, whereas a high number now reflects low confidence. For the combined data-layer maps the 'hotter' or more intense the colour then the higher the probability that the associated seabed has the potential to support Atlantic herring spawning.

The combined confidence in the 2013 methodology (Reach *et al*., 2013) was the sum of Total Normalised Scores for all layers at any one location. The combined confidence in this updated methodology is the multiplication of the converted Total Normalised Scores for all layers at any one location. The greater the number of over-lapping data-layers, the higher the probability that the seabed location represents Atlantic herring potential spawning habitat.

Table 2.7: Confidence assessment per individual layer (Adapted from: MarineSpace Ltd *et al*., 2013)

Confidence test	Method	Vintage	Positioning	Coverage	Quality Standards	Dataset Scoring Source	Total (Normalised)	Indicator of Spawning	Total Weighted Score	Total Normalised Score	New Total Normalised Score (Atlantic herring)
Range from 0 to >>	3	3	3	3	3		3	3	30	**5**	**0.1**
Weight	1	1	1	1	1			5			
IHLS (General)	3	3	3	3	3	MarineSpace	3	3	30	**5**	**0.1**
ESFJC	2	1	1	1	0	MarineSpace	1	2	15	**2.5**	**0.75**
Coull *et al*. (1998)	1	1	1	2	0	MarineSpace	1	2	15	**2.5**	**0.75**
EMODnet Preferred	2	3	3	3	3	MarineSpace	2.8	1	19	**3.2**	**0.50**
VMS	3	3	3	2	3	EMU	2.8	0	14	**2.3**	**0.75**
EMODnet Marginal	2	3	3	3	3	MarineSpace	2.8	0	14	**2.3**	**0.75**

	= Score provided by consortium
	= Value not altered in trials
	= Value tested in trials
xx	= Final combined confidence score

2.4.7 Data-layers Included in Combined Confidence

It was not possible to combine both the BGS and MAREA seabed sediment as indicators of spawning habitat in the MarineSpace Ltd *et al*. (2013) report, and it was advised that the best seabed sediment data are used at any individual licence area, as appropriate (MAREA data used as base map for the Humber and Anglian regions; and BGS data used as the base-map for the Outer Thames Estuary and South Coast regions). The EMODnet seabed sediment base map used in this updated method statement has an improved regional spatial coverage compared to the 2013 BGS map; and thus, the use of REC or MAREA data is not required. The OneBenthic Macrofaunal Assemblage dataset will be used to 'sense-check' the confidence in EMODnet seabed sediment compositions within marine aggregate regions.

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, within the same period. Where this temporal and spatial overlap occurs, 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 data are outside of a shared temporal overlap (i.e. where data has shared spatial interaction, but where those data were acquired at different times). These cases may result from data gaps e.g. Coull *et al.* (1998) used data up to 1998 but the IHLS dataset uses data from 2002-present. 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 in 1998, and between 2002 and present. It should be noted that the IHLS (High Abundance) data-layers can be included as a supplement to the heat map and, therefore, do not contribute to heat scores.

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 Atlantic herring spawning activity.

2.4.8 Range of Data Presented

If all layers were to coexist at one location, the minimum possible score would be the product of multiplying all individual layer scores. For seabed sediments, this would include only the EMODnet preferred habitat data-layer. For IHLS data, this would include only the IHLS (General) data-layer and not the IHLS (High Abundance) data-layers. Therefore, the 'Minimum Possible Data-layers Score' in this case is:

0.1 (IHLS) * 0.5 (EMODnet preferred) * 0.75 (ESFJC) * 0.75 (Coull *et al.*, 1998) * 0.75 (VMS) = 0.021.

Theoretically, a lower minimum combined score could be achievable if all data-layers had the minimum Total Normalised Score of 0.1 (5 in the 2013 method (Reach *et al*., 2013)) associated with each of them. This is not the case, so the Minimum Possible Data-layers Score is the 'real' minimum score that can be achieved using the data-layers available to the assessment.

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

Therefore, a maximum range based on the maximum number of layer scores that could theoretically overlap will be used in the analyses. In the MarineSpace Ltd *et al*. (2013) report, the actual results only extended up to 12 (out of a maximum of 16) as the data-layers required for the Maximum Possible Data-layers Score did not concurrently occur at any one location, i.e. they were spatially restricted in such a way that all data-layers were unable overlap in any single space within the study areas considered. The updated method will retain this principle, however, additional coverage of the datasets in the future may result in an increased spatial overlap of data-layers; resulting in the Minimum Possible Data-layers Score being achieved.

2.4.9 Categorisation of Data-layer Overlap – 'Heat'

By converting to the new 0.90-0.10 data-layer score range identified in Appendix C, and multiplying together overlapping data-layers, the interval range per heat group used within the 2013 methodology (Reach *et al*., 2013) are no longer applicable.

Due to the increased number of data-layers used in the assessment, and the potential for more layers to be included in the future, heat will no longer be grouped into intervals. This rationale has been incorporated to alleviate the need to reclassify groups within each assessment, and to reduce the likelihood of miss-reading the heat map where intervals are of similar colour (a by-product of introducing more data-layers). Further detail is provided in Subsection 2.5.

2.5 Heat Mapping

The heat mapping process has been sourced from the 2013 methodology (Reach *et al*., 2013), updated to reflect changes in the data-layer inputs as part of the method update. The final heat mapping outputs will differ from the 2018 output due to the update in scoring system, new data for the existing data-layers, and the addition of new data-layers.

Heat maps created by overlapping the base maps and data-layers described in Sections 2.2 and 2.3 allow a spatial assessment of receptor-pressure-exposure pathways. The updated weighted and normalised score values (0.90-0.10), generated from the confidence assessment, are no longer assigned to one of 4 'heat' categories of 'low', 'medium', 'high' or 'very high' Atlantic herring potential spawning habitat. Instead, the heat maps' colour scales will be continuous, and areas of 'low', 'medium', 'high' or 'very high' Atlantic herring potential spawning habitat will be inferred by professional judgement.

As described in Subsection 2.4.9, this rationale will provide a more robust assessment as data-layers evolve and prevent reassessment of defined scale bars with the addition, re-scoring, or removal of data-layers over time. Continuous scale heat maps have greater fine-scale resolution compared to heat maps with discrete classes and will better represent the greater sensitivity of the multiplicative scoring system.

Compared to a spatially restricted sampling regime, heat maps enable a more holistic and regional-scale consideration of potential spawning habitat provision and are more effective when relating the potential presence of such habitat and associated populations to wider ecological/ecosystem functionality. This information can be used by the licensee/applicant and consultees to better inform the magnitude of potential effects in relation to Atlantic herring spawning populations within individual licence/application areas; and more importantly to predator populations and assessment of any likely significant effects and assessment of adverse effects on integrity of designated sites supporting relevant classified and designated populations.

Discussions on specific mitigation or management measures will be undertaken on a site-specific basis following completion of the regional assessment. This methodology will accommodate updates to existing datasets and the addition of new datasets, so that future licence applications include the most relevant assessment of Atlantic herring potential spawning habitat.

2.5.1 Heat Map Construction

The initial heat map is constructed during Stage 1 of the methodology presented in this method statement and represents seabed sediment Folk classes at a population-scale. It shows preferred and marginal habitat sediments with the potential to support Atlantic herring spawning activity; in relation to Atlantic herring populations within the Greater North Sea ecoregion including the Waddensea, Skagerrak, and The East English Channel (refer to Section 2.2.1, see Appendix B for rationale for determining preferred and marginal habitat sediment classes).

The second heat map is constructed during Stages 2 and 3 of the methodology presented in this method statement and represents seabed sediment Folk classes at a regional-scale, showing preferred and marginal habitat sediments with the potential to support Atlantic herring spawning activity within each MAREA region. As these data-layers also map seabed sediments outside of the MAREA regions, these data will facilitate the assessment of any marine aggregate licence and application areas that are located outside of the MAREA boundaries.

Confidence in the location of Atlantic herring potential spawning habitat increases as the other data-layers are built into the heat map. This will provide an indication of Atlantic herring potential spawning habitats within and outside the UK EEZ, and form a single baseline to assess Atlantic herring impact pathways for future licence applications in all MAREA regions.

2.5.2 Future-Proofing the Methodology for Updating Datasets

The core principle of the methodology presented in this method statement is to improve upon the existing 2013 methodology (Reach *et al*., 2013) so that Atlantic herring potential spawning habitat undergoes the same assessment process in all MAREA regions using the most up-to-date data available. As data collection is a continuous process for most layers, such as the IHLS data-layers, future data-layer updates are necessary.

Data-layers used in the 2013 methodology (Reach *et al*., 2013) were updated in 2018 (MarineSpace Ltd, 2018a-d) so that the advice used in assessing the anthropogenic impacts on Atlantic herring was kept up-to-date. The updated method statement builds upon that principle by incorporating additional 'updateable' data-layers (such as the OneBenthic data-layer) and includes a population-scale aspect to the heat mapping process, to determine Atlantic herring potential spawning habitat outside of the MAREA regions.

Other datasets may be included and integrated before all data-layers are normalised to the number of data-layers now in the assessment (Section 2.4.3); provided they exhibit full spatial extent at the scale of the respective heat maps. Data-layers that would be useful for future updates include:

- Downs Recruitment Survey (for population scale mapping only, once approved for use in fisheries advice by the HAWG);
- Fine-scale seabed morphological features (such as ripples and ridges) that would indicate more-preferable Atlantic herring potential spawning habitats than flat areas currently assumed by the methodology;
- Variation in abiotic factors (such as oxygen concentration at the seabed) that would also provide a greater distinction between preferred, marginal, and unsuitable Atlantic herring potential spawning habitats.

However, to be useful in assisting potential spawning habitat assessment, these data must be wide-scale, certainly at a regional-scale, to provide any meaningful coverage, and thus not bias any heat mapping/assessment due to spatially highly localised data.

As data-layers are included into the methodology, the only values within the layer scoring assessments that will change are the individual scoring of each parameter for each data-layer (0-3) and the minimum possible data-layer score. Parameters will only change as data vintage or coverage increases, as updates to a data-layer's methodology should be presented as an independent data-layer and coverage will not decrease if the heat map scale remains the same. Changes to the minimum possible data-layer score will accentuate areas with multiple data-layer overlaps.

Conclusions drawn from this updated methodology will differ slightly from those drawn in the 2018 regional assessments as additional data-layers increase confidence in the presence of Atlantic herring potential spawning grounds. The new/updated scoring system contains subtle differences compared to the 2013 scoring system (Reach *et al*., 2013) when using the same data-layers as the 2018 assessments (MarineSpace Ltd *et al*., 2018a-d), however these differences do not significantly vary the conclusions as drawn within the 2018 assessments.

The output heat maps should not be interpreted as indicating areas of known Atlantic herring spawning grounds, rather as potential spawning habitats for Atlantic herring, and conclusions should always be drawn from the most recently available datasets at the time of assessment. It is, therefore, recommended that supplementary site-specific survey data and other seabed sediment interpolation data (e.g. Mitchell *et al*., 2019) are presented alongside the heat map, within environmental assessment applications; to ground-truth the EMODnet interpolation prior to drawing project-specific conclusions using the heat map. Where there is a weak or zero correlation between the supplementary data and the EMODnet interpolation, professional judgement should be used to determine the level confidence in the heat map identifying areas of potential spawning habitat for Atlantic herring.

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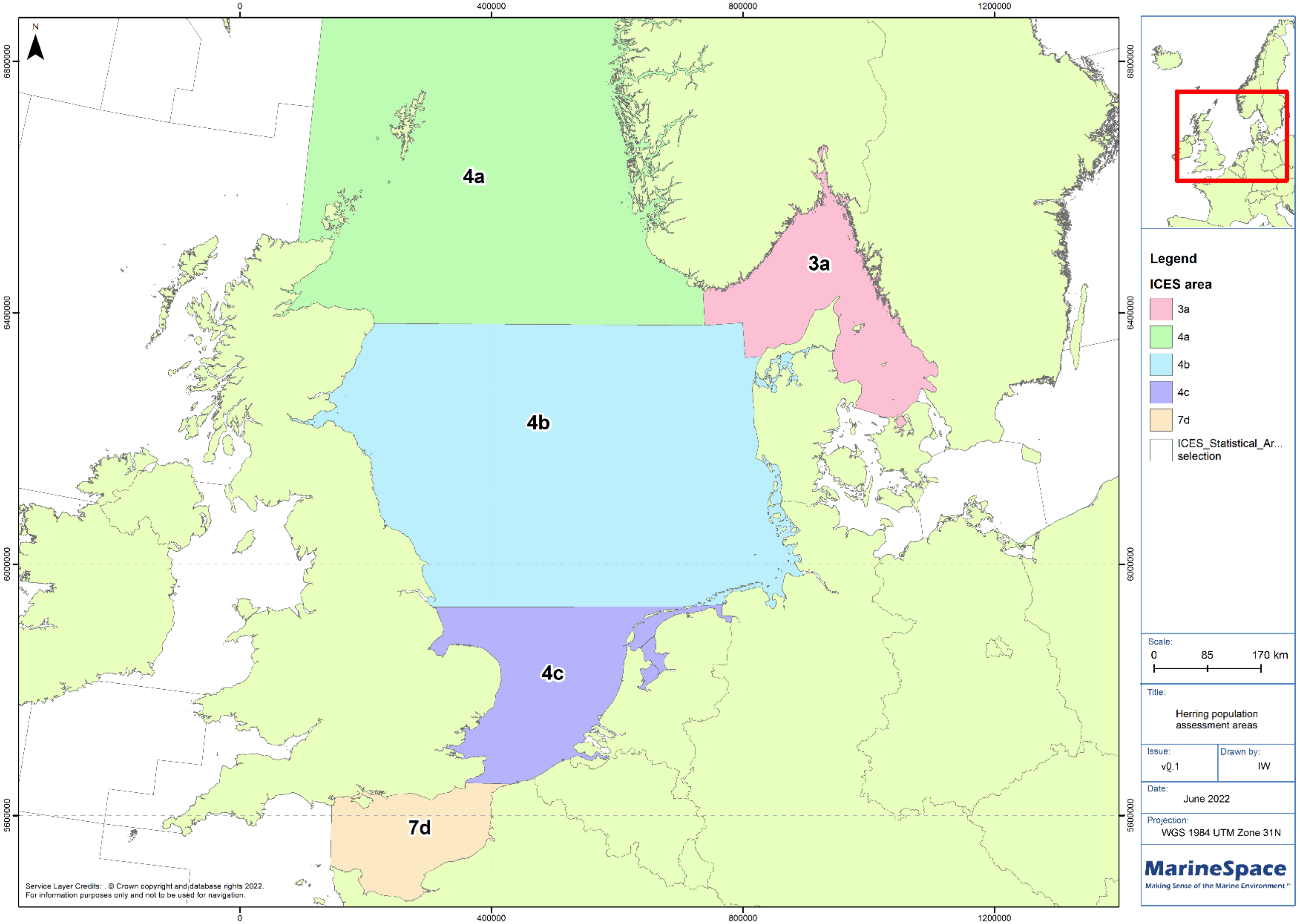
Appendix A

A.1 ICES Areas, Subareas, and Divisions for Atlantic Herring Fisheries

This appendix describes the compartmentalisation of The Greater North Sea by the International Council for the Exploration of the Sea (ICES), and describes the relationship between Areas, Subareas, and Divisions from which Atlantic herring stock data are assessed. Appendix A is supplementary information for Section 2.2.1 of the methodology report.

ICES has divided European seas into Subareas, and Divisions for fisheries data collection and management. The Greater North Sea ecoregion is classified as ICES Subareas 3-4 and split into Divisions 3a-b and 4a-c (Figure A1). For the purposes of this methodology related to the UK marine aggregate industry, divisions of interest for Atlantic herring stocks in the Greater North Sea, Skagerrak, and the east English Channel are 4a-b, 3a, and 7d (Figure A1).

Figure A1: The spatial extents of ICES Divisions (4a-c, 3a, and 7d) within ICES Subarea 4 - The Greater North Sea ecoregion, Skagerrak (Division 3a), and The East English Channel (Division 7d) (Source: ICES, 2017)



A.2 References Explicitly Reviewed for ICES Areas, Subareas and Divisions

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Appendix B

Appendix B has been sourced from the 2013 methodology and remains unchanged (Reach *et al*., 2013).

This updated method statement includes aspects of the methodology described in Reach *et al*. (2013), which is the intellectual property (IP) of the consortium for which MarineSpace Ltd was commissioned to develop the 2013 methodology: MarineSpace Ltd, ABP Marine Environmental Research Ltd, ERM Limited, Fugro EMU Limited, and Marine Ecological Surveys Limited. The aspects of the 2013 (Reach *et al*., 2013) methods, and associated IP, carried over into this updated method statement are explicitly identified within the relevant sections.

B.1 A Sediment Classification to Enable Determination of Atlantic Herring *Clupea harengus* 'Preferred' and 'Marginal' 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; Maravelias *et al.,* 2000; Maravelias, 2001; Skaret *et al.,* 2003; Geffen, 2009; Payne, 2010; ECA and RPS Energy, 2010a, 2010b, 2011; and ICES, 2021b). 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.

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 B1). 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 B1). 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 B2). This has become the standard particle size arrangement utilised in the broadscale 1:250,000 scale BGS seabed sediment maps and is widely reported elsewhere. The BGS seabed sediment maps are incorporated into the EMODnet seabed sediments data-layer used in this methodology and use the same Folk 16 classification.

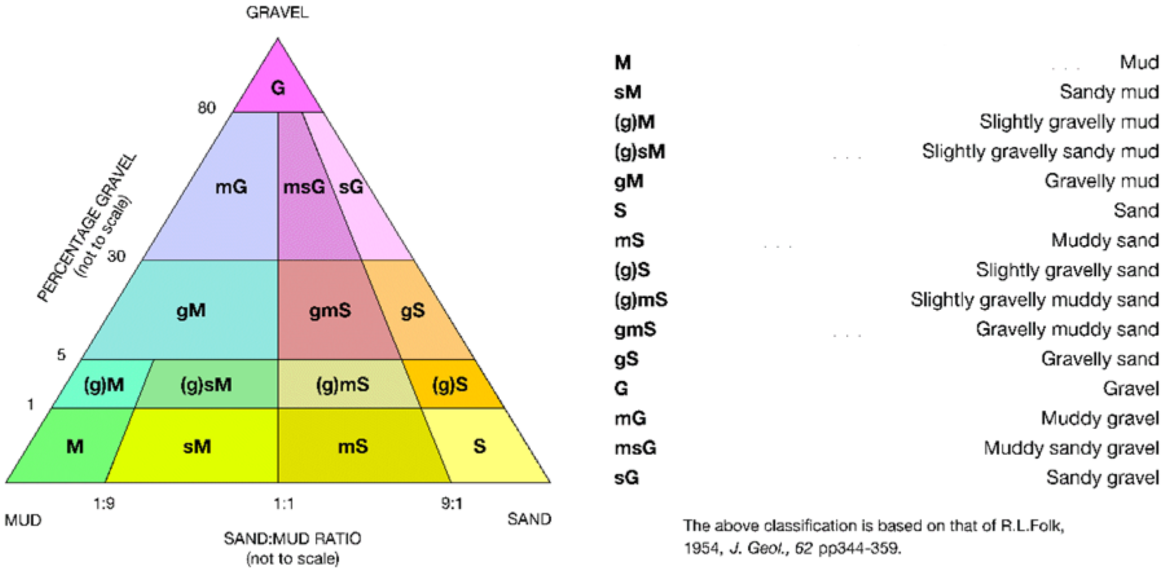
Table B1: Wentworth particle size descriptions (From: Wentworth, 1922)

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 B2: The British Geological Survey 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		

Figure B1: The Folk triangle and description of sediment codes. (From: Folk, 1954)



Consulting the papers and reports above it is evident that Atlantic herring are considered to have a strong affinity to spawn on seabeds that consist of ‘gravel’ with minimal fines and good oxygenation and high levels of aeration. Therefore, Cefas has advised that these attributes constitute suitable Atlantic herring spawning habitat.

The review and analysis of the source data for potential spawning habitat resulted in the overlay of the seabed surficial sediment classification presented in Table B2. The over-riding physical parameters are interpreted (from Cefas advice and source material, translated to the Folk classification, Table B2) such that:

- High gravel content (majority of the sediment being gravel) = >50% gravel;
- 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 display, 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 B3.

Figure B2: The Folk sediment triangle with partition of Atlantic herring 'preferred' spawning habitat. (Source: Folk, 1954)

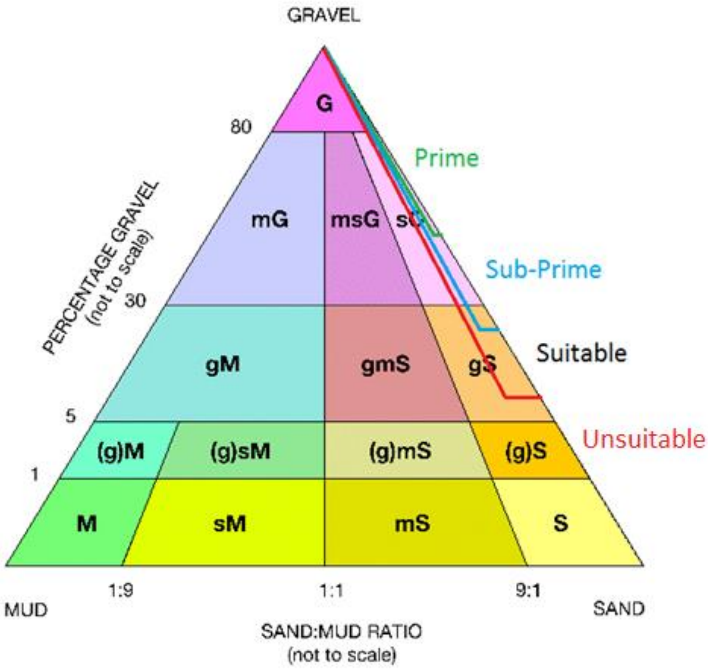


Table B3: The partition of Atlantic herring 'preferred' spawning habitat

% 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

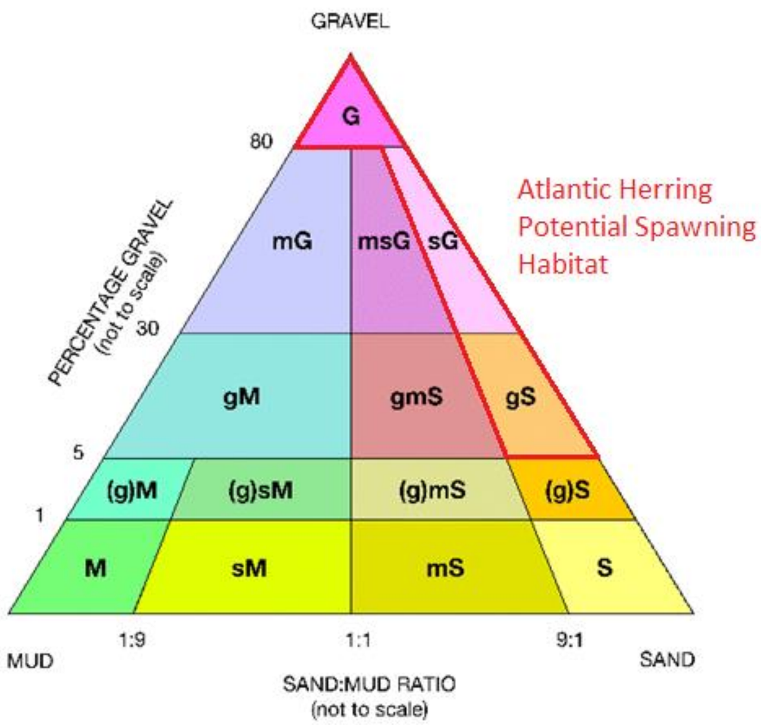
The translation of the sediment particle distribution from Table B1, Table B2, and Figure B2 is to a degree arbitrary, considering the wide range of habitat parameters in the literature reviewed. Therefore, the final potential spawning habitat classification has been extrapolated to each of the wider over-arching Folk sediment units as presented in Figure B3. 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;
- Gravel – G.

These Folk sediment units are mapped as Atlantic herring potential spawning habitat in the methodology presented in the main report to create the base maps (Stages 1 and 2), and subsequently in the screening exercise.

As comparison between Figure B.2 and Figure B.3 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 reworking of the BGS 1:25,000 data (which underpins the EMODnet data used in the main report) 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 MRW (MMO, 2013).

Figure B3: The Folk sediment triangle with Atlantic herring potential spawning habitat used in the methodology. (Source: Folk, 1954)



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Skaret G., Nottestad L., Ferno A., Johannessen A. and Axelsen B.E., 2003. Spawning of herring: day or night, today or tomorrow? Aquatic Living Resources, 16, pp. 299-306.

Appendix C

This updated method statement includes aspects of the methodology described in Reach *et al*. (2013), which is the intellectual property (IP) of the consortium for which MarineSpace Ltd was commissioned to develop the 2013 methodology: MarineSpace Ltd, ABP Marine Environmental Research Ltd, ERM Limited, Fugro EMU Limited, and Marine Ecological Surveys Limited.

C.1 Confidence Assessment Overview

C.1.1 Introduction

Confidence in the mapped Atlantic herring potential spawning grounds or the '*Atlantic herring indicator layers*' is required for all the exposure pathways (licence area and 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.

C.1.1.1 Datasets Considered

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

- Substrate Folk Classification: European Marine Observation and Data Network (EMODnet);
- Substrate Folk Classification: OneBenthic Macrofaunal Assemblages;
- Fishing Fleet: Vessel Monitoring Systems (VMS);
- Fishing Grounds: Eastern Sea Fisheries Joint Committee (ESFJC);
- Spawning Grounds: Coull *et al.* (1998);
- Spawning Grounds: International Herring Larvae Surveys (IHLS);
- Spawning Grounds: IHLS (High Abundance) (51-200 larvae/m^2);
- Spawning Grounds: IHLS (High Abundance) (201-600 larvae/m^2);
- Spawning Grounds: IHLS (High Abundance) (>600 larvae/m^2).

In all cases, the data inform the potential location of spawning grounds for Atlantic herring. 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 (Reach *et al*., 2024). 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.

C.1.1.2 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 coverage (all IFCAs) dataset were not supplied.

The REC substrate layer has been excluded because the EMODnet seabed substrates data utilises 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). Therefore, the use of the REC data in addition to EMODnet data would result in duplication of data.

MAREA data have increasing vintage, are site-specific, and are not linearly proportionate to wider spatial areas. The data collected and used within the EMODnet data-layer is more applicable at both population and regional scales, and therefore the MAREA data has also been omitted.

No longer using the REC/MAREA seabed sediment data is a deviation from the original 2013 method (Reach *et al.*, 2013). However, it should be noted that an updated MAREA process is likely to start during 2024, and if any new regional-scale data are acquired as part of that process, those data could be incorporated into this revised method in the future.

C.1.2 Confidence Test Method

C.1.2.1 Confidence in the Data

Following review of various approaches used to date, including MESH[1], UKSeaMap[2], and the MMO's approach (pers. comm.), a scoring proforma was developed (Reach *et al*., 2013; Latto *et al*., 2013) to apply to confidence assessments as shown in Table C1 below. This was adopted where there were no supporting spatial data to inform spatial variation in confidence.

The first five parameters (method, vintage, positioning, coverage, and quality standards) are concerned with the data themselves, i.e. how confident is the Marine Aggregate Environmental Impact Assessment (EIA) Working Group in the data being as described?

[1] http://www.searchmesh.net/default.aspx?page=1635

[2] http://jncc.defra.gov.uk/pdf/UKSeaMap2010_TechnicalReport_7_ConfidenceExternalReview.pdf

Table C1: Parameters used to assess the confidence of each data-layer

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

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

C.1.2.2 Confidence in the Data Indicating Atlantic Herring Potential Spawning Grounds

The final parameter, 'indicator of spawning', is not concerned with the data themselves, but the confidence in the data's ability to indicate Atlantic herring spawning grounds i.e. when there are no direct data on spawning measurements (e.g. seabed sediments), what confidence is there that the data may inform or indicate Atlantic herring spawning grounds? As this project is using the data to assess the likelihood or confidence of Atlantic herring potential spawning ground locations, this indicator parameter is fundamental to the outcome and, therefore, is heavily weighted. A weighting of 5 has been assigned following analysis of the data. A value of 5 results in this parameter holding the same weight as the preceding 5 parameters combined.

C.1.2.3 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. For example, with abundance, either there is spawning or there is not (presence/absence). It was concluded that only one dataset had spatial variations in a parameter that informs confidence: seabed sediment Folk class for the EMODnet dataset. This is addressed in the Individual layers' confidence assessment.

C.1.2.4 Scoring

For each parameter or confidence test shown, a score between 0 and 3 is assigned, where 0 = unknown and 3 = high confidence (Table C2).

Table C2: Confidence scoring categories for each parameter

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

*For the indicator of spawning, 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 was the case the layer should not be included for assessment. Therefore, a score of 0 for indicator of spawning = very low confidence.

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 C.3.

C.1.2.5 Combined Confidence

The combined confidence is the multiplication of all layers at any one location and represents the foundation for the heat mapping process.

C.2 Individual Layers' Confidence Assessment

C.2.1 Habitat from EMODnet Folk classes (substrate)

C.2.1.1 Confidence in the EMODnet 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 grounds for Atlantic herring. The confidence in the data is scored and justified within the first five parameters in Table C3.

No spatial variation is provided for the confidence in the substrate data (i.e. the data themselves).

Table C3: EMODnet Folk Map Confidence Scores

Confidence test	Score	Rationale
Method	2	This is assumed in absence of EMODnet input. The EMODnet substrate map and Folk classes in UK waters are from the BGS 1:25000 seabed substrate map series, which in turn are interpolated from PSA samples, multibeam and seismic surveys. Confidence for EMODnet/BGS SBS V3 has been inferred from that provided by Reach *et al*. (2013) and Latto *et al*. (2013).
Vintage	3	This is assumed in absence of EMODnet input. Whilst EMODnet data are collated from many datasets and was released in 2021, with the last BGS data update completed in 2020. The vintage should given a precautionary score of 2 once the BGS data is >5 years old.
Positioning	3	This is assumed in absence of EMODnet input. All locations are likely to be provided by accurate GPS systems.
Coverage	3	This is assumed in absence of EMODnet 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 EMODnet input. Data are clearly approved for use by EMODnet and BGS in national mapping.
Indicator of Spawning*	1 or 0	See Table C5 below. Varies by Folk class category, Folk class boundary representation.

*For the indicator of spawning, 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 was the case the layer should not be included for assessment. Therefore, a score of 0 for indicator of spawning = very low confidence.

C.2.1.2 Confidence in the EMODnet Data Indicating Potential Atlantic Herring Spawning Grounds

As detailed in the methodology report, Atlantic herring is known to prefer Gravel and sandy Gravel; and also have a marginal preference for habitats of gravelly Sand. Therefore, the Folk sediment class provides a spatially variable indicator of potential spawning grounds and hence a level of confidence.

However, the level of confidence in the Folk classes indicating Atlantic herring potential spawning grounds 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 Table C5 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. 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 (Reach *et al*., 2024). This is termed 'Folk category over represents/correctly represents' in the matrix below. These considerations are illustrated fully in the methodology report.

Due to these two factors, a matrix has been developed to assess confidence in the EMODnet data indicating Atlantic herring potential spawning 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 EMODnet data can indicate Atlantic herring potential spawning habitat with high confidence, as it is only an indicator. 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 Table C4.

Table C4: General matrix for confidence in the representation of sediment type in Folk categories

	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)

C.2.1.2.1 Atlantic Herring

As per the method statement for Atlantic herring, all of the three Folk categories that represent potential spawning habitat for Atlantic 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 matrix results are as follows (Table C5).

Table C5: Atlantic herring matrix for confidence in the representation of sediment type in Folk categories

	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

C.2.2 OneBenthic Macrofaunal Assemblages Point and Interpolation data

C.2.2.1 Classification of the OneBenthic Macrofaunal Assemblages Data into ICES Sub-rectangles

The OneBenthic Macrofaunal Assemblages data can be supplied in both point and interpolation formats from the Cefas Open Science OneBenthic portal:

- Point data – OneBenthic Baseline and Data Extraction Tools;
- Interpolation data – OneBenthic Layers Tool.

The OneBenthic Macrofaunal Assemblages point data will be used as a proxy for seabed sediment composition at a regional/license area specific scale due to its superior resolution over the interpolated data. The OneBenthic portal is a live Open Science portal with new data being added routinely, therefore the formation of this data layer should take account of new data as standard.

The OneBenthic Macrofaunal Assemblages dataset is the product of a 'big data' approach, in which 0.1 m^2 grab and core samples (to 1mm sieve resolution) collected during multiple surveys since 1998 are collated and classify the benthic macrofaunal species that are resident at each sampling location. Macrofaunal classifications and their associated sediment compositions were identified by Cooper and Barry, (2017). Table C6 shows the sediment type conversion from the Wentworth classification (Blott and Pye, 2011) to the Folk classification for each macrofaunal assemblage group (bio-cluster), based on the mean percentage of mud, sand, and gravel (Cooper and Barry, 2017). It should be noted that this conversion loses some resolution in the percentage composition of mud, however it enables direct comparisons with other data-layers in the combined confidence assessment. The Multivariate Index of Dispersion values represent the degree of variation in sediment composition within the bio-clusters.

Folk sediment classes that constitute preferred habitat (Gravel (G) and sandy gravel (sG) sediment classes), and marginal habitat (gravelly Sand (gS) sediment class) for Atlantic herring potential spawning grounds are represented by the faunal assemblages in Table C6, associated with sandy Gravel (sG) and gravelly Sand (gS) respectively. It is noted that the preferred Gravel (G) sediment class is not represented by faunal cluster groups in Table C6. The data will, therefore, act as a proxy for direct sampling of these areas. The data-layer will show the sediment class associated with the macrofaunal assemblage at each location. The point data is converted to a polygon format by associating the corresponding ICES sub-rectangles (for each location) with the sediment classification at each location. In ICES sub-rectangles that contain multiple samples, the most frequent sediment classification will determine the value of the sub-rectangle.

The interpolated data was created using the methods outlined in Cooper *et al*. (2019) and Cooper *et al*. (2022), using the same point data outlined above. The interpolation loses some of the resolution of the point data, but has a greater spatial extent, and may therefore be useful at a population-scale.

Table C6: OneBenthic Macrofaunal Assemblages sediment classification transformation from Wentworth to Folk

Bio Cluster	% Mud	% Sand	% Gravel	Wentworth Classification (Blott and Pye, 2011)	Folk Classification (Folk, 1954)	Multivariate Index of Dispersion (MVDISP)	Preference as Potential Spawning Grounds
A1	4	46	50	V(m)sG	sG	0.74	Preferred
A2a	8	63	28	(m)gS	gmS	0.73	Unsuitable
A2b	7	40	52	(m)sG	msG	0.81	Unsuitable
B1a	1	56	43	V(m)gS	sG	0.44	Preferred
B1b	2	54	44	V(m)gS	sG	0.44	Preferred
C1a	5	46	49	(m)sG	sG	0.9	Preferred
C1b	10	55	36	(m)gS	msG	0.8	Unsuitable
D1	15	75	10	(g)(m)S	gmS	0.99	Unsuitable
D2a	3	68	29	V(m)gS	gS	0.94	Marginal
D2b	17	77	6	(g)(m)S	gmS	1.05	Unsuitable
D2c	4	84	12	V(m)(g)S	gS	1.15	Marginal
D2d	3	93	4	V(g)v(m)S	(g)S	0.82	Unsuitable

C.2.2.2 Confidence in the OneBenthic Macrofaunal Assemblages Data

The OneBenthic Macrofaunal Assemblages data is used as a proxy for sediment type in this methodology, due to the limited variability in habitat for macrofaunal clusters. OneBenthic data utilises the Wentworth classification and requires a conversion to the Folk classification for comparison with other layers. The conversion is made by comparing the mean percentage of mud, sand, and gravel in the data and in each Folk sediment class, an established method within the British marine aggregates industry.

Table C7: OneBenthic Macrofaunal Assemblages Confidence Scores

Confidence test	Score	Rationale
Method	3	The OneBenthic Macrofaunal Assemblages dataset is a 'big data' approach that incorporates faunal assemblage types and locations from numerous surveys. Macrofaunal assemblages have limited variability in suitable sediment composition, and can therefore be used as a proxy for determining the sediment type in a given location.
Vintage	3	OneBenthic data draws upon many surveys undertaken at different time periods, from 1998-present, and the database is continuously updated as new surveys take place.
Positioning	3	OneBenthic data contain positional data representing sample locations.
Coverage	2	Sampling is conducted on a regular basis for a variety of industries, including the British marine aggregates industry through RSMP surveys. The spatial coverage is therefore excellent on a regional-scale. However, point data is limited to the UK Exclusive Economic Zone (EEZ) and therefore not appropriate for population-scale mapping. Conversely, the interpolation data is not limited by the EEZ and may be used at a population-scale, however it lacks the resolution of the point data for regional-scale mapping.
Quality Standards	3	Data collected by separate working groups, with each dataset checked for content and quality by the responsible Cefas group.
Indicator of Spawning	2	Direct indicator of marginal (but not preferred) substrate type.

C.2.2.3 Confidence in the OneBenthic Macrofaunal Assemblages Data Indicating Spawning Grounds

As the OneBenthic Macrofaunal Assemblage data represent direct measurements of substrate type, there is no inference, it is direct data on potential spawning grounds, as shown in Table C7.

C.2.3 VMS Fishing Fleet

C.2.3.1 Confidence in the VMS Data

As outlined in the table below, the confidence in the VMS data (first five parameters in Table C8) 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 C8: VMS 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. Future datasets may also include inshore VMS (I-VMS) data, which have not been integrated at the time of writing.
Vintage	3	2006 – present up to date and rolling 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.
Coverage	2	The entire North Sea and English Channel are covered by VMS data. VMS systems are compulsory (since 2004) for >18 m vessels, with increasing control for smaller vessels until 2011 (>12 m). Therefore, data coverage increases over time as the smaller vessels become included. No vessels <12 m are included in this data set, however the future inclusion of I-VMS data may increase this score.
Quality Standards	3	Data reviewed by the MMO and accompanied by MEDIN standard metadata.
Indicator of Spawning	0	The pelagic gears (industrial trawler, pelagic side trawler, pelagic stern trawler) target adult Atlantic herring, as well as many other species; and provide a low confidence indicator to spawning grounds. 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. These gears are likely to be targeting a number of species and may not be targeting Atlantic herring at all. Therefore, there is low confidence in this data as an indicator of potential spawning Atlantic herring.

C.2.3.2 Confidence in the VMS Data Indicating Atlantic Herring Potential 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 potential spawning grounds. As one gear type will target a number of species and not just Atlantic herring, the probability of it informing potential spawning grounds is very low. A full justification is provided in Table C8 above. However, in summary, pelagic gears are an indicator of Atlantic herring potential spawning populations, which could infer the presence of potential spawning grounds.

C.2.4 ESFJC Fishing Boundaries

C.2.4.1 Confidence in the ECFJC Data

The Eastern Sea Fisheries Joint Committee (ESFJC) (now the Eastern IFCA) GIS dataset specifically provides boundaries of Atlantic herring and sprat regions, together with month and season present, fishing gear used, and importance of any area to targeted/occasional fisheries (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 Table C9.

Table C9: ESFJC 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 the extent of the main fisheries within the ESFJC District (using best available data and fishermen's knowledge). 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	1	Data collection ceased after 2010, therefore most data is >12 years old and patterns in fishing grounds use may have changed.
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.
Coverage	1	Unknown how many data sources were used to compile broadscale coverage (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.
Indicator of Spawning	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.

C.2.4.2 Confidence in the ESFJC Data Indicating Spawning Grounds

As the ESFJC datasets are specifically for Atlantic herring and sprat, they are relevant to inform spawning grounds. The 'importance' field (target vs. occasional fisheries) 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.

C.2.5 Coull *et al.* (1998)

C.2.5.1 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 Table C10. 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 C10: 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 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 >15 years old and patterns in spawning habitat use 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.
Coverage	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 coverage 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.
Quality Standards	0	No evidence of any quality standards.
Indicator of Spawning	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, reducing confidence as an indicator of spawning.

C.2.5.2 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.

C.2.6 IHLS (General) Data

C.2.6.1 Classification of the IHLS (General) Data into ICES Sub-rectangles

The IHLS survey methodology has changed post-2017, in that the temporal scale of survey effort for the Downs Atlantic herring spawning population has been reduced. However, the remaining surveys are collected using pre-2017 survey protocols and, therefore, the post-2017 IHLS data remain comparable to the pre-2017 IHLS data. Refer to Section 2.3.5.1 of the methodology report for further information. As such, the IHLS (General) data-layer will contain a 2002-present time series for both the Banks and Downs populations represented by the Humber, Anglian, Outer Thames, East English Channel, and South Coast Regions.

The IHLS (General) dataset was supplied in point format (stations) for all years 2002 – present, 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 (i.e. density) was selected for the relevant larvae size range (in accordance with Reach *et al*., 2013):

- Larvae <10 mm in the Central North Sea;
- Larvae <11 mm in the eastern English Channel/southern North Sea, due to recognised increased hatching size (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 minimum no./m^2 at any one location during the time period assessed was calculated for each location, and therefore the IHLS (General) data-layer shows where spawning has occurred, but without an indication of its intensity.

Also due to this potential issue, any locations with <3 samples during the time period were removed from the dataset. This manipulation improved the interpolation within the ICES sub-rectangles substantially as there were one or more surveys that did not align to the survey grid structure used in the more recent pre-2017 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.

C.2.6.2 Confidence in the IHLS (General) Data

To align with other layers' assessment, the confidence should only relate to the standard/credibility of the data, not the scale of spawning as indicated by abundance/density data. Therefore 0 = absence and ≥1 = present. However, abundance/density data will not be lost in the assessment process, i.e. number count will still be used to inform any EIA/CIA through the inclusion of the indicative IHLS (High Abundance) data-layer within any assessment. There were no other fields considered suitable to inform spatial variation of confidence in the data. Table C11 shows the confidence in the data itself (first five parameters).

Table C11: IHLS (General) Data 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. 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). The dataset has a time series of 2002-present.
Vintage	3	IHLS data run from 2002-present.
Positioning	3	IHLS data contain positional data representing sample locations.
Coverage	3	Each sampling unit is one ICES statistical rectangle of 30 x 30 nautical miles and contains 9 sampling stations (represented by ICES sub-rectangles), thus providing a representative larvae sampling grid over the entire spawning area. The IHLS (General) data-layer includes all samples that have been surveyed ≥4 times (whether during one or multiple years). The value assigned to each ICES sub-rectangle are the maximum value of abundance 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.
Indicator of Spawning	3	Direct mapping of Atlantic herring spawning.

C.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, it is considered direct data on spawning grounds, as shown in Table C11.

C.2.7 IHLS (High Abundance) Data

The IHLS (High Abundance) data-layers should be considered as an indicator of hotspots of Atlantic herring potential spawning activity and used with caution at the assessment stage. These data-layers **do not** contribute to the heat map, but have been assessed for confidence in a similar manner to other data-layers.

Unlike the IHLS (General) data described in Section C.2.6, the IHLS (High Abundance) data will include abundance data collected over the 10 year period preceding any assessment application of the methodology, with the exception of the Downs population which will also include a 10-year baseline 2007-2017 dataset, in addition to the post-2017-present dataset. The pre-2017 baseline data-layers will be retained in the event that post-2017 data exceed a minimum 10-year period (in 2028/2029). The rationale behind this is to provide a baseline overview of the highest larval abundance data collected over a 10 year period, which the post-2017 IHLS survey data cannot accurately represent, and which can beneficially be used to identify the significance of under-representation of abundance within post-2017 IHLS data. For the Banks population, IHLS (High Abundance) data-layers will include the preceding 10 years-present IHLS data as a minimum (e.g. 2013-2023), to address the change in methodology described in the methodology report (Section 2.3.5.1, and Appendix D).

Abundance values are not a reliable measure of high intensity spawning sites as there is a potential for larvae to be aggregated within discrete ocean currents or eddies, and as such, reduce the confidence in hotspots as direct indicators of Atlantic herring potential spawning habitat. In an ecological context, it is well known that Atlantic herring do not spawn within the same grounds every year, and that spawning is likely influenced by small-scale conditions (such as eddies) at the seabed. As such, the IHLS (High Abundance) data-layers may provide an indicative function to identify areas that have the potential to accommodate intense spawning activity. These data-layers could be overlaid onto the heat map to identify areas of intense spawning activity which are not underpinned by all data-layers, and therefore may be overlooked as highly productive areas. In addition, trends in areas of IHLS (High Abundance) could be used to identify any patterns in spawning ground selection by individuals, which cannot be determined using the heat map alone due to a lack of site fidelity between years.

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. Unlike the IHLS (General) data-layer, all samples from each station were included, as opposed to ≥3 samples per station. The abundance (no./m^2) for each location was classified into 3 groups of 50-200, 200-600, and 601-max individuals per m^2. The groups were then then converted into 3 distinct polygons within shapefiles for each sampling year to allow comparison with the other data-layers. The exclusion of <50 individuals per m^2 reduces the degree of overlap with the IHLS (General) data-layer, and consequently increases the usability of the IHLS (High Abundance) data-layers to inform assessments. Where abundance (no/m^2) has not been pre-calculated and provided as a field in the ICES downloadable datasheet, then this will need to be calculated using the number and length (mm) of larvae columns in the ICES datasheet, noting the difference in larvae size range for the Banks (<10 mm) and Downs (<11 mm) spawning populations.

C.2.7.1 Confidence in the IHLS (High Abundance) Data

As stated in Subsection C.2.6.2, abundance data cannot be used to indicate spatial variation in confidence, and there were no other fields considered suitable to inform spatial variation of confidence in the data. Therefore, the IHLS (High Abundance) data-layers do not contribute to the heat mapping process. These data-layers should, instead, be used as a supplementary indicator of hotspots of Atlantic herring potential spawning activity in the assessment process. For example, abundance should still be used to inform EIAs/CIAs. There were no other fields considered suitable to inform spatial variation of confidence in the data. Table C11 shows the confidence in the data itself (first five parameters).

Table C12: IHLS (High Abundance) Data 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. 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). The dataset has a time series of 2002-present.
Vintage	3	IHLS data include present data, and therefore are given a score of 3. It is noted that data >5 years old would have a reduced vintage score of 2, but that these layers do not contribute to heat mapping.
Positioning	3	IHLS data contain positional data representing sample locations, that are identical to those used within the IHLS (General) data-layer.
Coverage	3	Each sampling unit is one ICES statistical rectangle of 30 x 30 nautical miles and contains 9 sampling stations (represented by ICES sub-rectangles), thus providing a representative larvae sampling grid over the entire spawning area. The IHLS (High Abundance) data-layers include all samples that have been surveyed ≥4 times (whether during one or multiple years). The value assigned to each ICES sub-rectangle are the maximum value of abundance recorded at any one location within the time period. (Only the central North Sea and East 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.
Indicator of Spawning	3	This data-layer's purpose is to identify hotspots of Atlantic herring potential spawning activity, as opposed to the location of spawning grounds. However, the data informing these data-layers uses the same direct sample dataset as the IHLS (General) data-layer and has therefore been assigned the highest indicator of spawning score in line with the IHLS (General) data-layer.

C.2.7.2 Confidence in the IHLS (High Abundance) Data Indicating Spawning Grounds

As the IHLS (High Abundance) data represent direct measurements of Atlantic herring larvae of the appropriate size classes, there is no inference, it is direct data on spawning activity, as shown in Table C11. Caution should be taken when comparing with potential spawning grounds, as the IHLS (High Abundance) data-layers consist of abundance data, which cannot infer spatial confidence in Atlantic herring potential spawning habitat due to its depth dependence. These layers should be used to provide context for assessments such as EIAs.

C.3 Combined Confidence Layer

C.3.1 Summary Individual Layers

Table C13 and Table C14 show the results of each of the confidence assessments per layer, plus the final single layer confidence score for Atlantic herring. A key is provided in Table C13 to show how these were calculated in Table C14.

Table C13: Key to Table C14

Item number	Parameter	Description
1	Method	Provided in confidence proforma (see earlier section). Range 0 to 3.
2	Vintage	Provided in confidence proforma (see earlier section). Range 0 to 3.
3	Positioning	Provided in confidence proforma (see earlier section). Range 0 to 3.
4	Coverage	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 (method, vintage, positioning, coverage, and quality standards) divided by the maximum total score, multiplied by the range (3)
8	Indicator of Spawning	Provided in confidence proforma (see earlier section). Range 0 to 3.
9	Total Weighted Score	Combined scores, calculated as sum of (method, vintage, positioning, coverage, and quality standards) + (5 X indicator of spawning).

Item number	Parameter	Description
10	Total Normalised Score	Total weighted score divided by maximum weighted score, multiplied by the range (5)
11	2022 Total Normalised Score (Atlantic herring)	The Total Normalised Score converted into a decimal system between 0.10 and 0.90. Details on this conversion are provided in Table C15.

Table C14: Final Confidence Assessment per Individual Layer

Confidence test	Method	Vintage	Positioning	Coverage	Quality Standards	Dataset Scoring Source	Total (Normalised)	Indicator of Spawning	Total Weighted Score	Total Normalised Score	New Total Normalised Score (Atlantic herring)
Range from 0 to >>	3	3	3	3	3		3	3	30	**5**	**0.10**
Weight	1	1	1	1	1			5			
IHLS (General)	3	3	3	3	3	MarineSpace	3	3	30	**5**	**0.10**
ESFJC	2	1	1	1	0	MarineSpace	1	2	15	**2.5**	**0.75**
Coull *et al*. (1998)	1	1	1	2	0	MarineSpace	1	2	15	**2.5**	**0.75**
EMODnet Preferred	2	3	3	3	3	MarineSpace	2.8	1	19	**3.2**	**0.50**
VMS	3	3	3	2	3	EMU	2.8	0	14	**2.3**	**0.75**
EMODnet Marginal	2	3	3	3	3	MarineSpace	2.8	0	14	**2.3**	**0.75**

	= Score provided by consortium		= Value not altered in trials		= Value tested in trials	xx	= Final combined confidence score

As detailed above, each individual layer is first scored on five parameters or tests relating to the data themselves: each of these tests result in a score of 0 to 3 (items 1 to 5 in the key above).

These scores are then summed for each individual layer but 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) (item 7) and is provided for reference only to show how the datasets differ, irrespective of their ability to indicate potential spawning grounds.

A single score is next provided for the confidence in the layer indicating potential spawning grounds (item 8). This test results in a score of 0 to 3.

The Total Weighted Score then combines all the scores together for Atlantic herring (item 9). The scores for confidence in the data (items 1-5) are added to the indicator score (item 8) 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 Normalised Score (item 10) is calculated by normalising the Total Weighted Score (item 9) to a range of 0 to 5 (i.e. by dividing by the total possible score of 30 and multiplying by the range, 5). These values could have ranged 0 to 3 as with the rest of the scores. However, this did not allow enough variation between the datasets. After trials with a range of numbers, a range of 5 was considered to show a suitable level of variation (Reach *et al*., 2013). In the updated 2022 methodology, these final data-layer scores were then converted to decimals using Table C15 below:

Table C15: Comparison between individual data-layer scores used in 2013 and 2022 methodologies

Year	No Data-Layers Present	Lowest Data-Layer Score				Highest Data-Layer Score
2013	0.00	1.00-1.90	2.00-2.90	3.00-3.90	4.00-4.90	5.00
2022	1.00	0.90	0.75	0.50	0.25	0.10

In all scores within the confidence assessment, a low number reflects high confidence in the data indicating Atlantic herring potential spawning grounds, whereas a high number reflects low confidence.

C.3.2 Combined Confidence Assessment

All contributing layers were combined together spatially. The combined confidence score for any one location was therefore calculated in ArcGIS as the multiplication of all layers' confidence scores. An example is provided in Table C16 below. The results of the confidence assessment can be seen in the associated GIS files, as well as the IHLS and OneBenthic ICES sub-rectangle classifications. The spreadsheets showing the above information are also made available.

Table C16: Example of Combined Confidence Score for Atlantic herring

Parameter	GIS Attribute Name	Value
VMS fishing fleet - pelagic	VMS	0.75
Coull *et al*. (1998) Herring	Coull *et al*.	0.75
ESFJC Atlantic herring	ESFJC	0.75
IHLS (General)	IHLS	0.10
EMODnet Preferred	EMODnet_Pref	0.50
Combined score	TOTAL	0.021
Simplified combined score	CONF_TOTAL	High

C.4 References Explicitly Reviewed for the Confidence Assessment Overview

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Appendix D

This explanatory note has been drafted by Cefas and updated by MarineSpace Ltd

D.1 Reduction in the survey period of the southern North Sea IHLS survey effort for the Atlantic herring Downs spawning stock, and consideration of this within this method

Downs herring stock spawning activity varies spatially across the extent of the spawning ground, but also temporally through the spawning season (November to January inclusive). Broadly, spawning activity starts in November in the spawning grounds located in the southern Eastern Channel region and here, larval abundances are highest earlier in the spawning season. In northern parts of the spawning grounds in the southern North Sea, spawning activity occurs in December and larval abundances are highest later in the spawning season (Dickey-Collas *et al.,* 2009; ICES, 2022). This pattern can be seen in the ICES reports relevant to the IHLS survey efforts, the below example (Figure D1) is taken from ICES (2016) where panel a) reflects larval abundance in the second half of December, panel b) reflects larval abundance in the first half of January, and panel c) reflects larval abundance in the second half of January.

It is important to recognise that the sampling intensity of the IHLS survey of the Downs herring spawning component was changed after 2017. Until 2017, the southern North Sea and eastern English Channel (SNS) IHLS survey for the Downs herring population was conducted as three separate sampling event surveys which all followed the same methodological approach, utilising the Gulf VII plankton sampler to collect larvae in the earliest developmental stages (yolk-sac larvae; <11 mm). These were carried out as one survey in the 3rd quarter of each year between 16-31 December, and two surveys in the 1st quarter of the following year: one between 1-15 January, and one between 16-31 January.

From 2017 onwards, sampling of the IHLS survey of the Downs herring spawning component changed so that the third IHLS survey (between 16-31 January) was discontinued, and the Downs Recruitment Survey was implemented in order to further understanding of foraging and recruitment of more developed herring larvae in the German Bight and Skagerrak/Kattegat area (ICES, 2018). The Downs Recruitment Survey (DRS) is not a replacement for the discontinued IHLS survey as it utilises a different sampling method, occurs at a different time of year and in a different location, and collects more developed foraging larvae (>11 mm, mostly between 20-40 mm). The DRS samples larvae from all the SNS spawning areas and the survey does not identify or distinguish which natal spawning location they are from. For these reasons, the DRS data cannot be used to inform the heat mapping exercise and has not been considered within this methodology at any stage.

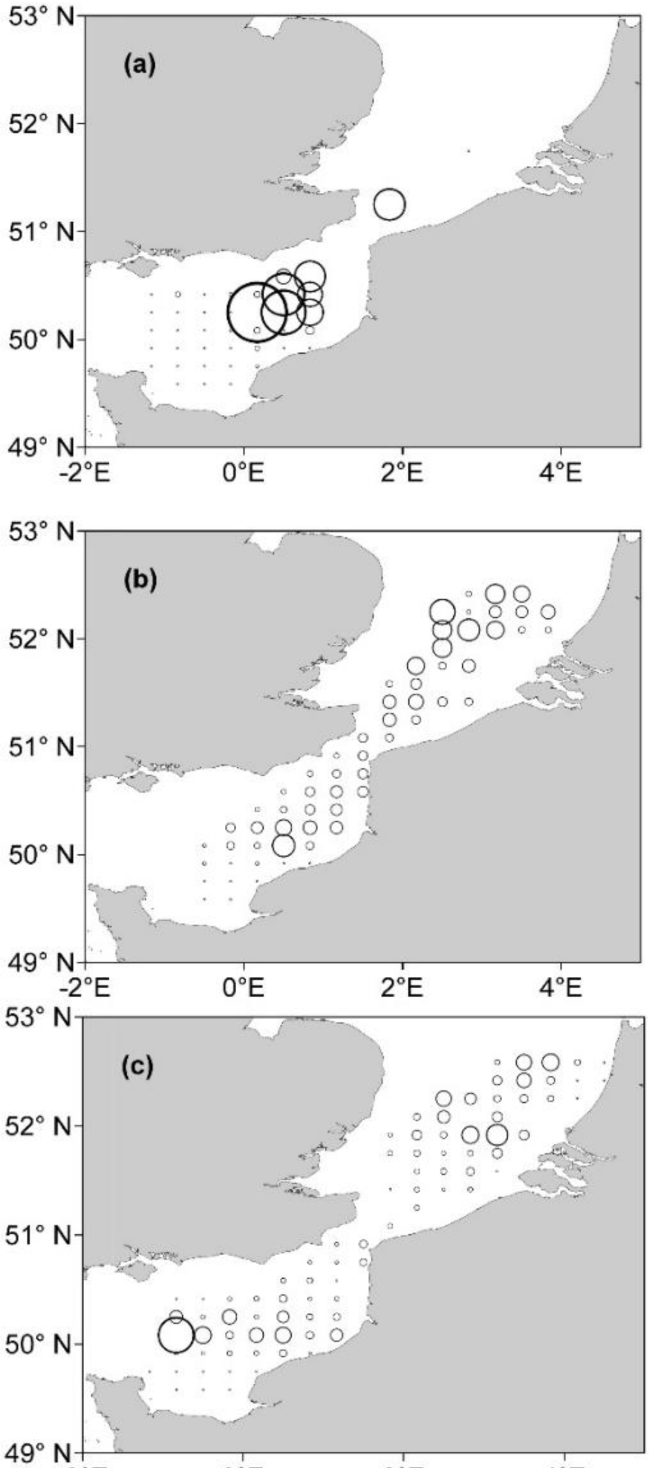

Figure 2.3.2.2 a-c: North Sea herring - Abundance of larvae < 11 mm (n/m²) in the southern North Sea as obtained from the International Herring Larvae Survey in the second half of December 2015 (a) and in the first (b) and the second half (c) of January 2016 (maximum circle size = 1 600 n/m²).

Figure D1: Spatial and temporal variation in Downs herring stock spawning activity across the extent of the spawning ground, through the spawning season (ICES, 2016).

With this in mind, the full temporal extent of spawning activity by the Downs herring stock is no longer fully reflected in SNS IHLS data collected post-2017. For this reason, the IHLS data applicable to this method have been differentiated for the IHLS (General) and IHLS (High Abundance) data layers as follows:

- For the **Banks herring spawning stock**, in the relevant areas of the central and northern North Sea (inclusive of the Humber aggregate dredging region), the IHLS (General) data layer will contain IHLS data for 2002-present, as the IHLS surveys in which these data were collected have not changed. The IHLS (High Abundance) data layer will draw on a minimum of 10 years of the most recent larval data preceding an assessment. Refer to Section C 2.7 for detail;
- For the **Downs herring spawning stock**, relevant to the southern North Sea and eastern English Channel (inclusive of the Anglian, Outer Thames, East English Channel and South Coast aggregate dredging regions), the IHLS (General) data layer will contain IHLS data for 2002-present, as the method used to categorise 0-ringer larval presence/absence has not changed between pre- and post-2017 datasets. The IHLS (High Abundance) layers for the Downs stock will present a pre-2017 larval abundance baseline using 10 years of pre-2017 IHLS data (the years 2007-2017). Post-2017 larval abundance will also be presented, using a minimum of 10 years of post-2017 IHLS data[1].

It should be noted that this does not mean that post-2017 IHLS data for the Downs herring stock cannot be used to support relevant assessments. IHLS data collected after 2017 by the two remaining Downs herring IHLS surveys *are still relevant* to assessing likely impacts to the Downs herring spawning stock. This data is still applicable to determining areas of potential spawning habitat in the northern portion of the Downs herring spawning grounds, however, this data may underrepresent the density of larvae present, given that the herring larval density for this area is typically highest in the northern spawning grounds in the later part of the spawning period, which is no longer incorporated into the Downs IHLS survey. Further guidance on how post-2017 IHLS data for Downs herring is incorporated is provided within Section C 2.7 of Appendix C (the High Abundance IHLS data layers), but it should be noted that these data layers do not contribute to the heat mapping exercise).

The 2017 onwards data remains relevant to the assessment of impacts arising from dredging (and other activities), but this data should be presented as separate supplementary evidence, in the form of a complementary map or figure. Please refer to Section C 2.7 of Appendix C for further details on complementary mapped data layers for the Downs spawning component.

[1] This method statement was written in 2023/2024 and at this time, 6 years of post-2017 IHLS data for the Downs herring stock was available. As subsequent years of data become available, 10 years of the most recent larval data should be incorporated to form the post-2017 IHLS (High Abundance) data layers.

D.2 References Explicitly Reviewed for Appendix D

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