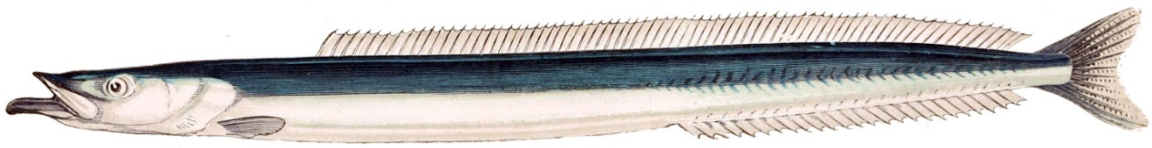
MarineSpace

Making Sense of the Marine Environment ™

Identifying and Mapping Sandeel Potential Supporting Habitat: An Updated Method Statement



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MarineSpace Limited has been commissioned 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; to develop revised a method to map the distribution and extent of seabed habitat that has the potential to be used as habitat by sandeel species, *Ammodytes marinus*, *A. tobianus, Hyperoplus lanceolatus*, *H. immaculatus* and *Gymnammodytes semisquamatus* in relation to marine aggregate licence and application areas. This revised methodology is based upon previous work conducted in 2013 by MarineSpace Ltd in partnership with ABP marine environmental research Ltd, ERM Limited, Fugro EMU Limited, and Marine Ecological Surveys Limited.

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The cover image of Greater Sandeel *Hyperoplus (Ammodytes) lanceolatus* 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 Licenses

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
EIA	Environmental Impact Assessment	Process by which the effects of a plan or project on the environment, and its constituent parts, are 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
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 sandy Gravel which sandeel may select as habitat. This sandeel habitat has adequate sediment structure but will only support low numbers of sandeel – 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 sandeel favourably select as habitat (Sand, slightly gravelly Sand and gravelly Sand) – 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)	Sandeel habitat which has the ideal sediment structure and supports the greatest number of sandeel
PIZ	Primary Impact Zone	The zone within which impacts resulting from the passage of the draghead over the seabed surface occur – also known as the direct impact zone
RAG	Regulatory Advisors Group	A group of statutory and technical advisors to the Regulator the MMO regarding marine aggregate extraction

		operations and impacts. Members include Natural England, Cefas, JNCC and Historic England
REC	Regional Environmental Characterisation	Broadscale description at a regional sea scale of the environment associated with marine aggregate extraction licenses.
	Sandeel	There are 3 key species of sandeel present in UK waters where exposure pathways to environmental effects from marine aggregate operations may exist. These are the Greater Sandeel *Hyperoplus lanceolatus* Le Sauvage, 1824; the Lesser Sandeel *Ammodytes tobianius* Linnaeus, 1758; and Raitt's Sandeel *A. marinus* Raitt, 1934. The less common species of Corbin's sandeel *Hyperoplus immaculatus* and smooth sandeel *Gymnammodytes semisquamatus* have also been identified as potentially present (Wheeler *et al*., 1978). Where 'sandeel' is referred in this report it should be read to collectively represent these 5 species
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)	Sandeel habitat which has acceptable sediment structure and supports an intermediate number of sandeel
Suitable (Habitat)	Sandeel habitat which has adequate sediment structure to support high numbers of sandeel

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1 Introduction

1.1 Sandeel Species

Sandeel species are known to exclusively feed on the phytoplankton and zooplankton which inhabit the water column by filter-feeding during the daylight hours (Freeman *et al*., 2004). Due to their small size and large numbers, they are an important prey items for numerous fish species, as well as seabirds and marine mammals (Engelhard *et al*., 2008). Therefore, sandeel species are an important part of the marine food web acting as an umbrella species linking primary productivity (from plankton biomass) to the higher trophic levels (apex predators). Reductions in biomass of these species can have impacts ranging up the food chain to higher trophic levels and apex predators. Links have been found between population decreases in seabird species, such as the black-legged Kittiwake *Rissa tridactyla*, and reductions in general sandeel recruitment (Furness, 2002; Frederiksen *et al*., 2004; Daunt *et al*., 2008; Birdlife International, 2008; JNCC, 2021).

It has been suggested that sandeel species display a high level of site fidelity, making them potentially vulnerable at a sub-population-level to direct habitat loss (removal) (Jensen *et al*., 2011). Due to the known environmental effects associated with the mechanical removal of sediment surface layers, the resources targeted (sands and gravels), and the overlap with known sandeel population ranges, it is likely that there are effect-receptor pathways. Quantification of these pathways and footprints and assessment of magnitude of effects will set context and allow environmental assessment for marine aggregate licence areas and applications, both individually and cumulatively.

1.2 Aims and Objectives

The objectives of this report are to revise and update the existing heat mapping methodology described by Latto *et al.* (2013), as used in regional sandeel habitat assessment baselines for the UK marine aggregates industry (MarineSpace Ltd *et al*., 2013; MarineSpace Ltd , 2018a-d); and to present the considerations of environmental effects from marine aggregate extraction activities on habitat that potentially supports sandeel, at population- (international/national) and regional-scales.

The analyses and revisions to the 2013 methodology (Latto *et al*., 2013) have considered variation in the distribution of sandeel populations in the wider North Sea 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 habitat for relevant sandeel 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 screening of all marine aggregate extraction licence and application areas against spatial overlap with areas of seabed that contain sandeel potential habitat. 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 population-scale.

There are several seabed user industry activities that are likely to interact with sandeel potential supporting habitat in the UK EEZ, and across the entirety of population and sub-population ranges now able to be mapped, such as:

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

These activities should be considered as part of a Cumulative Impact Assessment (CIA), at a suitable scale, when assessing any possible damage or deterioration to sandeel potential supporting 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 sandeel potential supporting habitat method.

The methodology builds upon consultation and advice provided by the Marine Management Organisation Regulatory Advisors Group (MMO RAG[1]). Identification of sandeel potential habitat and assessment of any receptor-exposure pathways will allow suitable mitigation to be established. This in turn may alleviate additional pressures on populations of seabirds and other sensitive apex predators.

This method statement expands on the Latto *et al*. (2013) methodology that informed the Environmental Impact Assessment (EIA) of marine aggregate extraction activities and associated environmental effects on sandeel potential habitat. The Latto *et al*. (2013) methodology was updated in 2018 to incorporate more recent datasets for baseline characterisation of sandeel potential habitat (MarineSpace Ltd, 2018a-d). However, recent statutory consultation and advice has required variations from the existing Latto *et al*. (2013) methodology. A reassessment of the regional sandeel supporting habitat suitability mapping has been agreed through discussions between The Operators and the MMO RAG. The fundamental differences between the Latto *et al*. (2013) and the methodology presented here are:

1. The addition of new data-layers, including;
    a. OneBenthic Macrofaunal Assemblage data;
    b. Sandeel Presence data;
2. Integration of both population- and regional-scale mapping;

[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.

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 potential supporting habitat for sandeel species, and the spatial analysis and screening exercise presented in this method statement, are intended to generate information of sufficient resolution and confidence to support any assessment of potential supporting 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 sandeel habitat preferences advances, and/or when new data become available.

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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.

This methodology update includes aspects of the methodology described in Latto *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 (Latto *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] 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.

2 Methods

The mapping methodology considers the autecology of sandeel species in the North Sea and English Channel is considered and the validity of mapping appropriate data-layers (including any limitations and confidence) are applied using a structured and tiered methodology.

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 Environmental Impact Assessment (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 CIA depends upon screening spatial interactions between marine aggregate licence and application areas and the potential supporting habitat for sandeel species. *In lieu* of actual impact hypotheses to test, the environmental effects and effect-receptor pathways of potential impact on sandeel habitat from marine aggregate extraction are only associated with the primary impact zone (PIZ) and not the secondary impact zone (SIZ).

The effect-receptor pathways related to the PIZ that needs to be assessed include the direct removal of sandeel habitat and mortality of individuals, along with physical alteration of the structure of the sediments from direct contact with the draghead. The effect-receptor pathways related to the SIZ, such as environmental effects from sediment plumes and sediment mobilisation i.e. smothering of *in situ* individuals, and the alteration of potential supporting habitat by fining from settling sands are not considered detrimental to sandeel species (Pérez-Domínguez and Vogel, 2010). Therefore, this methodology will only be conducted using the PIZ footprint and not that of the SIZ.

The MMO and RAG have considered the environmental issues regarding entrainment of adult sandeel 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 this 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) dataset, 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 analysis.

It is also important to note that after an initial larval dispersal period, sandeel display a degree of site fidelity (Haynes and Robinson, 2011; Jensen *et al.*, 2011). Therefore, it is important to consider the state of seabed habitats at the end of the licence term. The area of seabed associated with re-colonisation potential, post-dredging, is represented by the PIZ only. Determinations regarding the potential for re-colonisation will also be drawn from an applicant's Environmental Statement regarding requirements to leave the seabed in an appropriate state (similar to pre-dredge) at the end of the term of the licence period.

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

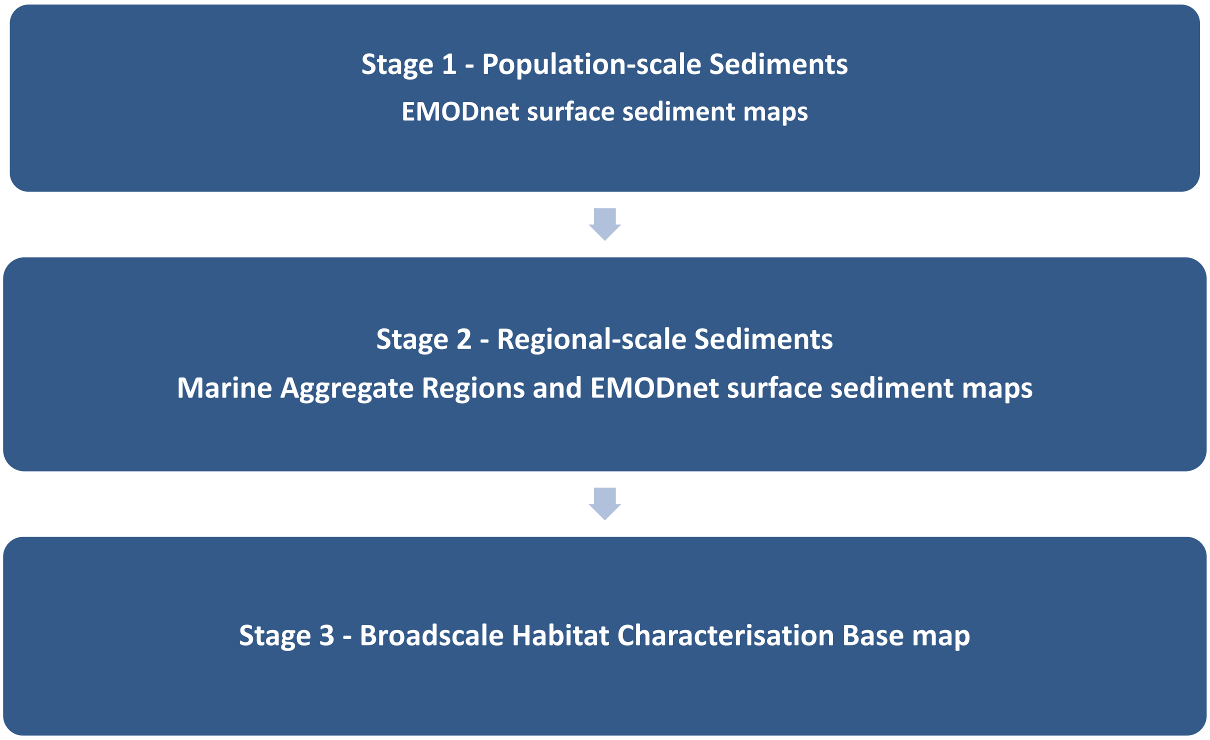
The Primary Impact Zone:

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

The methodology presented in this report uses a tiered approach to map habitat and ecological space and assess appropriate receptor-exposure pathways: scoping down from sandeel 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 assessment 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 sandeel habitat characterisation



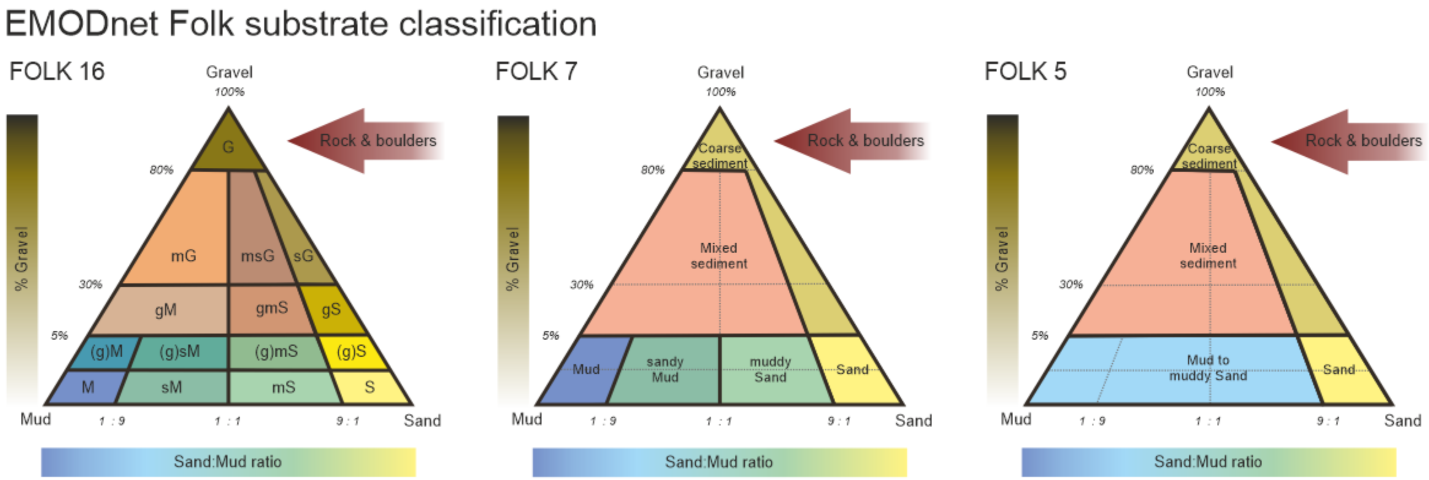
2.1 Review of Seabed Surface Data

In developing the Latto *et al*. (2013) method used in the MarineSpace Ltd *et al.* (2013) and MarineSpace Ltd (2018a-d) reports, 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 the 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 habitat for sandeel species. Appendix A of MarineSpace Ltd *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 British 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. However, the BGS data-layers do not capture the full extent of the North Sea sandeel population distributions outside of 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 sandeel potential habitat at 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, the use of EMODnet seabed substrate 1:250k multiscale dataset has therefore been considered appropriate to display sandeel potential preferred and marginal sandeel 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 Map

This section describes the stages used to create the base map that will provide the foundation layer for applying further data-layers in Stage 3 of this methodology (Section 2.3).

2.2.1 Stage 1: Population-scale Mapping of Sandeel Distribution

The North Sea sandeel stock consists of 3 predominant species, generally considered to be in decline due to sea warming-induced poor recruitment (Arnott and Ruxton, 2002) and fishing activity (Dunn, 2021):

- Greater sandeel *Hyperoplus lanceolatus*;
- Lesser sandeel *Ammodytes tobianus*;
- Raitt's sandeel *Ammodytes marinus*.

Fisheries stock assessments and environmental impact assessments within the marine aggregate industry classify sandeel species as on group due to similar habitat requirements and exposure pathways. Sandeel populations can be classified by the location of sandbank features within specific fishing grounds, due to high site fidelity and a lack of genetic population distinction throughout the European shelf (Wright *et al*., 1998; Wright *et al*., 2019).

Sandeel populations were previously identified and distinguished as ICES Sandeel Areas 1r and 4 within ICES Subarea 4 – The Greater North Sea, following renewed advice from ICES on the delineation of sandeel stocks (ICES, 2017; MarineSpace Ltd, 2018a-d), however the vast spatial extent of both Sandeel Areas 1r and 4 (and all other Sandeel Areas in The Greater North Sea) overrepresent suitable sandeel habitats. Figure 2.3 shows the location of sandeel fishing grounds, that better represent the distribution of sandeel populations, and will provide the basis for sandeel population-scale mapping in this report (From Wright *et al.*, 2019). ICES Sandeel Area SA1 in Figure 2.3 are referred to as Sandeel Area 1r (located within ICES Subarea 4, Divisions 4b-c) in this report, and SA2 is screened out for the British marine aggregate industry. For reference, the relative spatial extents of ICES Areas, Subareas, and Divisions are shown in Appendix A.

Assessing the spawning requirements at a population-scale presents numerous challenges for sandeel species, primarily due to their burrowing nature. Unlike many other North Sea species, which lay eggs on the substrate, such as Atlantic herring *Clupea harengus*, sandeel species are pelagic spawners. Quantifying the area of suitable spawning habitat required to maintain sustainable stocks is therefore difficult and can only be based on the area of suitable habitat for settlement – in other words the extent of suitable habitat for sandeel colonisation. Table 2.1 summarises the most recent North Sea sandeel stock data for Sandeel Area 1r that characterises the sandeel populations that spawn within the UK's Exclusive Economic Zone (EEZ) (ICES, 2021a; ICES, 2021b), and should be used as a reference for subsequent assessments at a regional-scale. The total area required for spawning in Sandeel Area 1r assumes:

- Average mature fish (age 2 – based on >80% maturity in age 2+ classes) of 0.0128 kg;
- One male spawner per female spawner;
- The area of spawning habitat equals the area of the seabed containing mature adults.

Figure 2.3: The distribution of sandeel fishing grounds, a proxy for population distribution, within the North Sea and associated ICES Sandeel Areas (From Wright *et al.*, 2019)

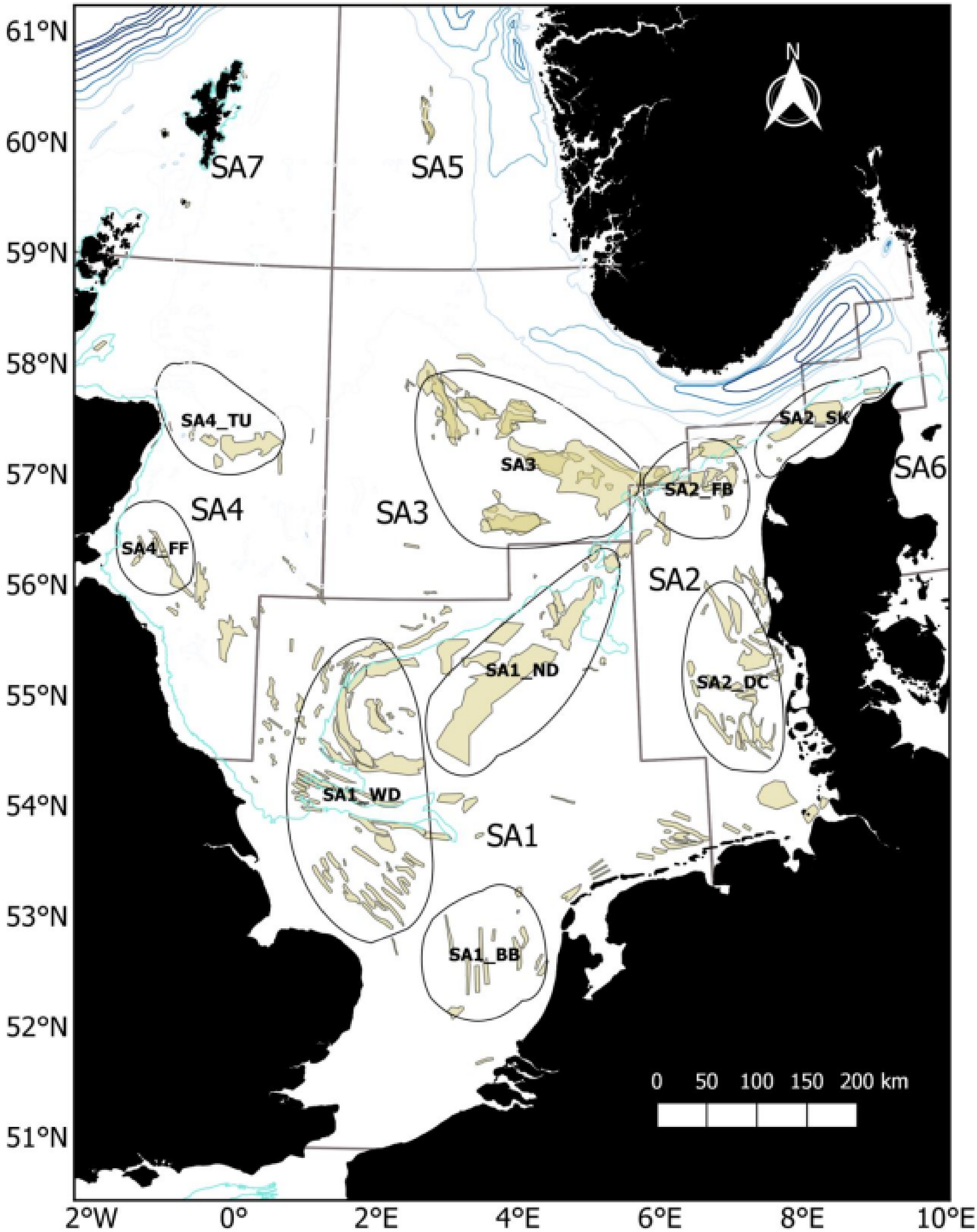


Table 2.1: Sandeel stock data for Sandeel Area 1r to inform the extent of habitat required by the current Spawning Stock Biomass (ICES, 2021b; Holland *et al*, 2005; ICES, 2021a)

Average Weight per Adult Fish (kg)	Density of Females (no per m^2)	SSB (kg)	Total Area Required in Sandeel Area 1r (km^2)
0.0128	15-35	130,336,544	145.46-339.42

It should be noted that Sandeel Area 4 has recently closed a proportion of its spatial area to fishing as a result of local seabird declines. Future updates to this methodology should consider the status of the appropriate Sandeel Area when investigating spawning stock biomass (SSB) values, as these values will underrepresent the actual sandeel stock in that area. For the UK marine aggregate industry, all North Sea (Humber, Anglian, and Outer Thames regions) licence areas and application areas will be specific to Sandeel Area 1r, which is open to fishing (at the time of publication).

Sandeel habitat preference has been investigated and described in various peer reviewed papers and grey literature (Macer, 1966; Reay, 1970; Wright *et al*., 1998; Wright *et al*., 2000; Holland *et al*., 2005; van der Kooij *et al*., 2008; Greenstreet *et al*., 2010; Haynes and Robinson, 2011; Jensen *et al*., 2011; Latto *et al.*, 2013). In developing the methodology presented in this report Latto *et al.* (2013) reviewed the available data and classifications. Close liaison has been sought with fish ecologists and scientists at Cefas as well as regular consultation with the MMO. Particular attention has been made to the parameters concerning particle size distribution data available and any ranges of preference, or thresholds used previously, to categorise sandeel habitat in UK waters. Appendix B presents relevant extracts of the source material and data used in this method statement and provides an interpolation of these data using the Folk sediment triangle (Folk, 1954).

The Folk sediment classification has been used as this is also the classification scheme used to underpin the BGS 1:250,000 scale surface sediment maps. This sediment classification has subsequently been used within the REC and MAREA reports. Using the Folk (1954) classification enables compatibility of the final sandeel habitat EIA and CIA with different products (e.g. MAREAs, marine planning areas) and data sources (e.g. BGS 1:250,000 maps).

Wright *et al*. (2000) and Holland *et al*. (2005) recently described sandeel habitat requirements as medium to coarse sand of a diameter between 0.25 and 2 mm, with a mud content of less than 10% (particles < 63 µm). Wright *et al*. (2000) demonstrated this range in a series of controlled laboratory-based experiments and the results were replicated in field observations by Holland *et al*. (2005). Greenstreet *et al*. (2010) investigated the determinations made in Holland *et al*. (2005) and presented an alternative analysis. These latter two studies have reviewed and reconsidered all of the previous work on sandeel habitat preference (cited above). Therefore, the basis for determining sandeel habitat used in this methodology is derived from the Holland *et al*. (2005) and Greenstreet *et al*. (2010) work and is presented in detail in Appendix B. This classification and the sediment divisions proposed were ratified by the MMO RAG at a meeting held on 16 February 2022 (MMO, 2022) and through subsequent discussions. It is important to note that the use of these sediment divisions will over-represent the full range of sandeel habitat due to the percentage of mud component within them (see Appendix B for detail).

Holland *et al*. (2005) and Greenstreet *et al*. (2010) also concluded that suitable sandeel habitat can include a gravel component. Neither of their classifications align with the Folk classification (Folk, 1954) boundaries; both exceeding the threshold of 30% gravel between gravelly Sand and sandy Gravel. As described in Appendix B it is important to note that the sandy Gravel division (Folk, 1954) accounts for a range of 30-80% gravel content. Holland *et al*. (2005) state that suitable sandeel habitat has a threshold of 35% or less for gravel content. Greenstreet *et al*. (2010) cite a threshold up to 50% gravel for sub-prime habitat and between 50-80% gravel for suitable habitat. Comparing the Holland *et al*. (2005) and Greenstreet *et al*. (2010) conclusions it is apparent that there is a discrepancy between the respective classifications falling within/across the sandy Gravel division. This sediment division can greatly over-represent the suitability of the habitat for sandeel (given the range of gravel content between 30-80%).

In a precautionary manner the methodology in this report includes the sandy Gravel division as a mapping layer; however, this is considered marginal habitat for sandeel and is accorded less confidence than the preferred habitat sediment divisions.

Without re-examining all of the BGS data used in developing the 1:250,000 scale seabed sediment maps (and therefore the EMODnet maps), a direct representation of the habitat is not possible (see Appendix B for detail). The MMO and RAG agreed that such an exercise is beyond the requirements of any specific EIA (as required under the MWR). Therefore, the best fit, but precautionary, Folk sediment classification as described in Appendix B and presented in Figure 2.4, will be used in this methodology.

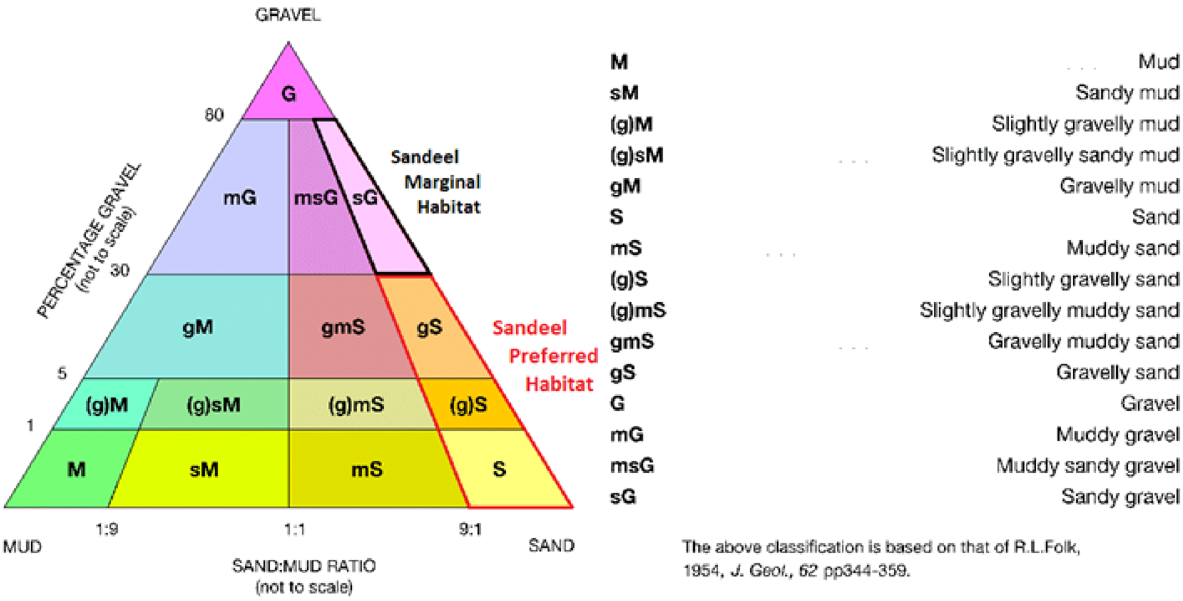
The Folk classification (Folk, 1954) sediment divisions' best describing the preferred habitat for sandeel species in UK waters are:

- Sand – S;
- slightly gravelly Sand – (s)gS;
- gravelly Sand – gS.

The Folk classification (Folk, 1954) sediment division used to describe marginal habitat for sandeel species in UK waters is:

- sandy Gravel – sG.

Figure 2.4: Folk triangle with sandeel preferred and marginal habitat indicated. (Source: Folk, 1954; Holland *et al.*, 2005; Greenstreet *et al.*, 2010)



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

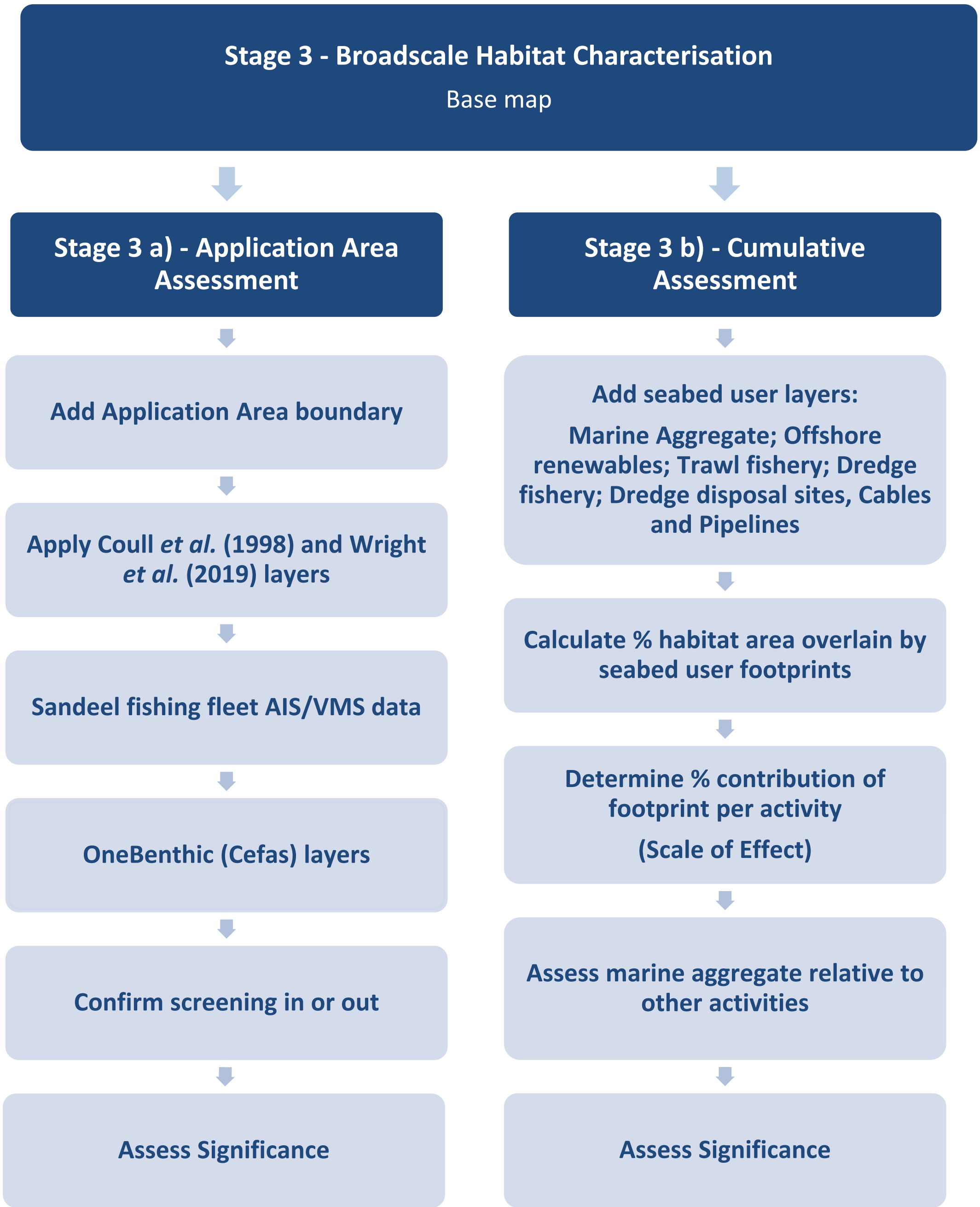
Stage 2 uses the EMODnet data (as identified above) to map the sandeel habitat at a regional-scale. The regional extent of the habitat can be identified and calculated, regarding the specific licence and application areas and the associated impact zones. This value will subsequently be used when calculating the level of interaction between application/licenced 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 EMODnet data as REC/MAREA data have increasing vintage, are site-specific, and are not linearly proportionate to wider spatial areas. For these reasons, and the spatial extent of the updated EMODnet data layer, 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 (Latto *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 sandeel, although the methodology also applies to Atlantic herring. 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 population (international/national) scale (as identified in Stage 2). This value, along with the base-map, can be used to inform both the individual licence or application area and cumulative assessments at Stages 3a) and b) respectively, through parallel processes (Figure 2.5).

Figure 2.5: Screening levels to enable application area, licence area, and cumulative assessments between Marine Aggregate Application Areas and sandeel preferred and marginal habitat



2.3 Stage 3: Refined Heat Maps to Identify Sandeel Habitat

Once the base map has been created, additional data-layers can be overlaid to improve confidence in determining the spatial extent of sandeel potential habitat 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 sandeel habitat.

It is at this stage that the 2013 methodology (Latto *et al*, 2013) becomes integrated with this updated methodology. Subsections 2.3.1-2.3.3 have been sourced from the 2013 methodology, updated to include the most recent data available. Subsection 2.3.4 is a new data-layer for the updated methodology. Subsections 2.3.5 and 2.3.6 are sourced from the 2013 methodology.

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 PIZ i.e. an active dredge zone (ADZ) may occur anywhere within the licence/ application area boundary during the period of the term applied for (15 years). As mentioned in Section 2 the direct removal of preferred and marginal seabed habitat within the PIZ of a licence/application area is the receptor-exposure pathway considered in this methodology. The secondary effects of aggregate extraction, increased concentrations of suspended sediments and smothering, are considered inconsequential to sandeel species (Pérez-Domínguez and Vogel, 2010). Therefore, the receptor-exposure pathway analysis will only be conducted with the PIZ footprint and not the SIZ. The PIZ can be used to support determinations regarding post-dredging habitat recovery and the potential for re-colonisation of these seabed areas by sandeel.

No licence or application areas are screened out at this stage to allow an initial mapping layer to be established against which further screening layers may be applied through Stages 3a)ii and iii. Therefore, although a licence or application area may not directly overlap a mapped area of habitat there may be additional data, e.g. fishing activity data, which indicates exposure pathways. This enables a reasonable level of conservatism to be incorporated into the methodology and ensures that all possible exposure pathways are considered before the final screening exercise at Stage 3a)iv. This rationale is also applied to Stages 3a)ii and iii.

2.3.2 Stage 3a)ii: Known Sandeel Supporting Grounds (Coull *et al.*, 1998; Wright *et al.*, 2019)

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 Wright *et al.* (2019) data-layer considers known sandeel fishing grounds in the North Sea and associated sandeel stocks used within ICES assessments. Wright *et al*. (2019) concluded that populations of sandeel are unlikely to interact beyond a separation of 200 km, and as such, the data-layer can be considered an indicator of separate sandeel populations. These locations are primarily distributed outside of the influence of aggregate licence areas, and thus the data-layer should be primarily considered as an indicator of sandeel potential habitat at a population scale, although there is potential for overlap with the SA1_WD stock and licence areas within the Humber region that should be considered within any Humber regional assessments.

The Coull *et al*. (1998) and the Wright *et al*. (2019) data-layers are mapped, and any overlap with licence area boundaries are identified. Due to uncertainties (low confidence) with the validity of the Coull *et al*. (1998) and the Wright *et al*. (2019) data-layers capturing the full range of sandeel habitat, licence and application areas that fall outside the envelope are still progressed to the next stage of screening. This is also important for areas of seas with minimal coverage provided within the Coull *et al*. (1998) data-layer such as the south coast of England. As the Wright *et al.* (2019) data-layer does not represent populations within the Outer Thames region or the East English Channel region, the known sandeel supporting grounds are limited to the Coull *et al*. (1998) data-layer in these regions.

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 sandeel habitat, the spatial layer should be enhanced where possible. The methodology will supplement the Coull *et al*. (1998) layer with sandeel-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 sandeel-targeted fisheries will be mapped and considered part of the exposure pathway.

Fisheries landings data are not considered fit-for-purpose to be included in this methodology as an indication of targeted fisheries activity (due to the high uncertainty associated with linking any port of landing to the area of seabed where fish were caught). This rationale is deemed sound and supported by the MMO and RAG (MMO, 2013, 2022).

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

Stages 3a)i – iii are broadly similar to the Latto *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 accessibility) have been made that could provide more insight to the location and spatial extent of sandeel habitat. 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 (Latto *et al.*, 2013).

Whilst currently in a developmental phase, OneBenthic could provide a 'one-stop-shop' for baseline data used in ESs for all marine development projects, and thus increase the level of data transferability between each sector e.g. aggregates, renewables, and oil and gas. In time, a holistic picture of the distribution of seabed features, sediments and habitats will be created. 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 Baseline Tool (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 licenced areas. In addition, the OneBenthic Sandeel Presence dataset, extracted from the OneBenthic Taxa Search Tool (refer to Appendix C), will be incorporated into the heat mapping process as direct evidence of sandeel supporting habitat.

Datasets exported from OneBenthic may have a 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 base map. As time progresses, the macrofaunal assemblage data-layer has the potential to become relevant to the wider seabed sediment composition and distribution, at which point it would 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: Confirm Screening In or Out

Spatial overlap between licence or application areas 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 area or application area screened in at Stage 3a)i and more than one of the data-layers from Stages 4a)ii and 4a)iii. Sediment habitat layers describing the range of preferred habitat sediment divisions (Sand, slightly gravelly Sand and gravelly Sand) (from the base map, Stages 1 and 2) will possess the highest confidence. Areas identified as marginal habitat (sandy Gravel) will have a lower confidence than areas of preferred habitat. This is due to the fact that the sandy Gravel division (Folk, 1954), and associated mapping layer, may contain a large representation of seabed sediments with a greater than 50% gravel component (see Section 2.1 and Appendix B). Accordingly, the extent of this habitat may over-represent potential habitat available to sandeel species. As such the confidence in this data-layer is reduced.

Following the seabed sediment layers, descending confidence will be ascribed to OneBenthic data, targeted fisheries data, then the Coull *et al*. (1998) layer. Individually the data-layers each hold a degree of confidence that sandeel species are present, this is increased when 2 or more of these layers overlap with one another; with the highest confidence associated with a convergence of preferred habitat with the targeted fisheries data and the Coull *et al*. (1998) layers. Lower confidence will be applied where there is a convergence of marginal habitat with the targeted fisheries data and the Coull *et al*. (1998) layers. Licence or application areas in which 2 or more data-layers are present but with no overlap will also carry a lower level of confidence in the presence of sandeel habitat. Again, overlap with preferred habitat will rank higher than any overlap with marginal habitat.

Licence and application areas with no spatial overlap with any of the data-layers described in Stages 4a)i-iii above will be screened out of further assessment. They will forgo an EIA for sandeel preferred or marginal habitat as it is demonstrated that there is no receptor-exposure pathway. For any 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 in an EIA, or management advice, where the licence or application area boundary is considered to = PIZ = potential area for habitat removal.

2.3.6 Stage 3b: Cumulative Impact Assessment (CIA)

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 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 MAREAs and Stage 3a)i such that it is assumed that the boundary of the licence area or application area is representative of the PIZ i.e. an ADZ may occur anywhere within the application or licence area boundary during the period of the term applied for (15 years). As mentioned previously, the SIZ is excluded from the CIA as the secondary effects of aggregate extraction are considered inconsequential to sandeel species (Pérez-Domínguez and Vogel, 2010).

The CIA will consider the footprint of all the appropriate seabed user activities at a MAREA-scale. The boundary of the regional-scale CIA will be the same as indicated and mapped at Stage 2 of this methodology. The relevant seabed user activities identified as interacting with sandeel preferred and/or marginal habitat are listed in Table 2.2 below.

Where sandeel preferred and/or marginal habitat is located beyond the regional boundaries (delineated in Stage 3), then those habitat components will be considered as outside the scope of this CIA. However, this information may be usefully drawn into other components of an EIA e.g. when regarding interactions between sandeel species and sensitive apex predators such as seabirds as classified populations of nearby Special Protection Areas (SPAs). These considerations will utilise the larger scale data-layers from Stages 1 and 2 to inform any such assessment.

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 CIA to be conducted as part of the EIA.

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 supporting habitat across the range of North Sea sub-populations as identified by Wright *et al.* (2019).

Table 2.2: Seabed user activities likely to interact with sandeel preferred and marginal 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 (Latto *et al*., 2013), updated to reflect changes in the data-layer inputs as part of the methodology update. The final scoring system is new for the methodology update; however, the main structure of the individual data-layer confidence assessment has been maintained from the 2013 methodology, for ease of comparison between the 2013 methodology and the updated methodology.

Confidence in the mapped potential supporting areas for sandeel species is required for all the exposure pathways related to the PIZ only (See Section 2). 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 Latto *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), 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 sandeel than for Atlantic herring (see Kyle-Henney *et al*., 2024).

2.4.1 Data Considered

The spatial datasets considered in the confidence assessment to inform the location of sandeel habitat will include the layers presented in Stages 1-3 in Sections 2.2-2.3:

- Seabed sediment Folk classification: EMODnet;
- Seabed sediment 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) and Wright *et al*. (2019);
- Spawning grounds: OneBenthic sandeel presence data.

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 Latto *et al*. (2013) and Reach *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 supporting habitat, 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 sandeel potential habitat, 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: Latto *et al*., 2013; Reach *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 Habitat	Suitability of the dataset to inform of sandeel habitat	5

As previously discussed, it has been identified that sandeel are faithful to a discrete area of seabed sediment after recruitment (Jensen *et al.*, 2011), thus regions of spawning (Coull *et al.*, 1998) may act as a proxy for adult occupation of habitat.

The final parameter, ‘indicator of habitat’, is not concerned with the data themselves, but the confidence in the data indicating habitat i.e. when there are no direct data on habitat measurements (such as seabed sediments), what confidence is there that the data may inform or indicate sandeel potential habitat? As this methodology uses data to assess the likelihood or confidence of sandeel potential habitat 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 sandeel habitat. This assessment is only concerned with parameters that reduced certainty about the data so, for example, variation in fishing time (VMS) does not reduce certainty in the data. 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.

It was concluded in the 2013 methodology (Latto *et al*., 2013; Reach *et al.*, 2013) and the MarineSpace Ltd *et al*. (2013) report that only two datasets had spatial variations in a parameter that informs confidence: seabed sediment Folk class for each of the BGS and MAREA datasets; which in the methodology presented 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 habitat’ (final parameter in Table 2.3), a score of 0 would mean it is unknown whether the dataset can be used to infer sandeel habitat 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 habitat’ = 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 habitat', 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 (Latto *et al*., 2013), and then converting to the new updated decimal scoring system (see Appendix C for detail).

2.4.4 Confidence in the Seabed Habitat Sediments Data Indicating Potential Sandeel Habitat

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

The level of confidence in Folk classes indicating sandeel potential habitat 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 Sand indicating sandeel potential habitat (hence the 'preferred habitat sediment') than sandy Gravel (the 'marginal' habitat sediment) (Appendix B; Latto *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 sandeel potential habitat, or not, e.g. the Folk category sandy Gravel contains sediment types outside of the preferred range for sandeel habitat, i.e. there is the possibility that the Folk sandy Gravel class may contain >50% gravels which is unfavourable to support sandeel populations. 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 sandeel habitats with high confidence as it is only an indicator, i.e. direct measurements of habitat carry much greater confidence. Therefore, the matrix is scored from 0-2 (Table 2.5). As detailed in Section 2.4.3 above, where scoring the indicator for habitat, a zero score does not imply 'unknown', but 'very low' instead.

Of the 4 Folk categories that represent sandeel potential habitat sediment class (Sand (S), slightly gravelly Sand ((g)S), gravelly Sand (gS), and sandy Gravel (sG)), only the marginal habitat sediment class sandy Gravel over-represent the habitat divisions, due to the percentage of unfavourable gravel above the tolerance of sandeel species (see Appendix B for detail). This reduces the confidence in the EMODnet data-layer indicated by the Sandeel Matrix results (Table 2.6).

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: Sandeel Matrix – Application of the General Matrix to the EMODnet Folk sediment classes

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

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

2.4.5 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 habitat', taking both the quality of the data into account as well as their suitability to be used to indicate locations of potential supporting habitat for sandeel (see Appendix C for detail).

Each individual layer is first scored on 5 parameters or tests relating to the data themselves: each of these tests result in a score of 0 to 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 supporting habitat.

A single score is provided next for the confidence in the layer indicating potential supporting habitat for sandeel. 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 sandeel is then calculated by normalising the total weighted score for sandeel 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 (Latto, *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 (Latto *et al.*, 2013).

The new 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 (Latto *et al*., 2013) will reduce the relative confidence of existing data-layers in the heat mapping process. The conversion to a range of (very low = 1.00, low = 2.00, medium = 3.00, high = 4.00, very high = 5.00), 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 the 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 (Latto *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 OneBenthic Sandeel Presence data as part of the updated methodology (but still using the 2013 scoring system) would have increased the maximum value to >16.00. 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. More detail will be provided in Subsections 2.4.8 and 2.5.

Using the new, revised method, contrary to the 2013 methodology (Latto *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 sandeel potential habitat.

The combined confidence in the 2013 methodology (Latto *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 potential supporting habitat for sandeel.

Table 2.7: Example final confidence assessment per individual layer, with the 2013 and new total normalised scores for reference. Note these data-layers and scores correspond to those identified within the 2013 methodology and not the new updated methodology (Sourced: MarineSpace Ltd *et al.*, 2013)

Confidence test	Method	Vintage	Positioning	Coverage	Quality Standards	Dataset Scoring Source	Total (Normalised)	Indicator of Habitat	Total Weighted Score	Total Normalised Score	New Total Normalised Score (Sandeel)
Range from 0 to >>	3	3	3	3	3		3	3	30	**5**	**0.1**
Weight	1	1	1	1	1			5			
OneBenthic Sandeel Presence	2	3	3	3	3	MarineSpace	2.8	2	24	**4**	**0.25**
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	**1.5**	**0.75**
Wright *et al.* (2019)	1	3	2	2	0	MarineSpace	1.6	2	18	**3**	**0.5**
EMODnet Preferred	2	3	3	3	3	MarineSpace	2.8	2	24	**4**	**0.25**
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

2.4.6 Data-layers Included in Combined Confidence

It was not possible to combine both the BGS and MAREA seabed sediment as indicators of supporting 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 the methodology presented in this method statement has an improved spatial coverage compared to the 2013 BGS map, with regard to marine aggregate regions; and thus, the use of MAREA data as a substitute 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 and will be overlaid onto the heat map as an indicative layer, as opposed to contributing directly to heat scoring.

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 sandeel, within the same period. Where this temporal and spatial overlap occurs, a higher certainty that the data are indicating sandeel potential habitat can be deduced. This is not to say that there is a lack of confidence where there is a spatial overlap of data-layers, but these are outside of a shared temporal overlap. These cases may result from data gaps e.g. Coull *et al.* (1998) used data up to 1998 but VMS dataset is from 2006-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 sandeel, with a level of certainty that this may have been the case in 1998, and between 2006 and present.

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 sandeel populations.

2.4.7 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. Therefore, the 'Minimum Possible Data-layers Score' in this case is:

0.25 (EMODnet preferred) * 0.25 (OneBenthic Sandeel Presence) * 0.5 (Wright *et al*., 2019) * 0.75 (ESFJC) * 0.75 (Coull *et al.*, 1998) * 0.75 (VMS) = 0.013.

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 (Latto *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 supporting habitat' or 'quantity of overlap in layers to indicate supporting habitat', i.e. the more layers present that indicate supporting habitat for sandeel, the higher the confidence; providing that all layers cover all licence regions. The scoring provides an assessment-specific (using the data available at the time of the assessment) one-off national presentation of data, showing the range of data and theoretically possible overlaps, indicating the potential for an area of seabed to support sandeel populations.

Therefore, a maximum range based on the maximum number of layer scores that could theoretically overlap will be used in the analyses. The data-layers required for the Maximum Possible Data-layers Score may not concurrently occur at any one location, i.e. they can be spatially restricted in such a way that they were all unable overlap in any single space within the study areas considered. The updated methodology will retain this principle, however, additional data coverage of the original datasets in future updates may result in an increased spatial overlap of data-layers and extend to the minimum possible data-layers score.

2.4.8 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 (Latto *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 will be provided in Subsection 2.5 below.

2.5 Heat Mapping

The heat mapping process has been sourced from the 2013 methodology (Latto *et al*., 2013), updated to reflect changes in the data-layer inputs as part of the methodology 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' potential supporting habitat for sandeel. Instead, the heat maps' colour scales will be continuous, and areas of 'low', 'medium', 'high' or 'very high' potential supporting habitat for sandeel will be inferred by professional judgement.

As described in Subsection 2.4.8, 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 supporting 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 sandeel 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 sandeel potential 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 sandeel; in relation to sandeel populations within the Greater North Sea ecoregion, 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 sandeel populations 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 region boundaries.

Confidence in the location of potential supporting habitat for sandeel increases as the other data-layers are built into the heat map. This will provide an indication of potential supporting habitat hotspots within and outside the UK EEZ and form a single baseline to assess sandeel 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 (Latto *et al*., 2013) so that potential supporting habitat for sandeel 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 VMS data-layer, future data-layer updates are necessary.

Data-layers used in the 2013 methodology (Latto *et al*., 2013) were updated in 2018 (MarineSpace Ltd, 2018a-d) so that the advice used in assessing the anthropogenic impacts on sandeel was kept up to date. The methodology presented in this method statement builds upon that principle by incorporating additional 'updateable' data-layers (such as the OneBenthic data-layers) and includes a population-scale aspect to the heat mapping process, to determine potential supporting habitat for sandeel 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:

- Fine-scale seabed morphological features (such as ripples and ridges) that would indicate more-preferable sandeel potential habitats than 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 sandeel potential habitats;
- Confirmation of adult sandeel presence at known locations (e.g. from grab samples or anecdotal records) would provide further direct indication of potential supporting habitat;
- Sandeel abundance based on targeted sandeel surveys (e.g. the North Sea Sandeel Survey) which are carried out using the appropriate protocols and sampling equipment (e.g. sandeel dredge) would provide an indication of sandeel densities across areas of supporting habitat.

However, to be useful in assisting potential 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 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 potential supporting (and therefore spawning) habitat for sandeel. The new updated scoring system contains subtle differences compared to the 2013 scoring system (Latto *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 supporting habitat for sandeel, rather potential supporting habitats for sandeel, 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 supporting habitat for sandeel.

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Appendix A

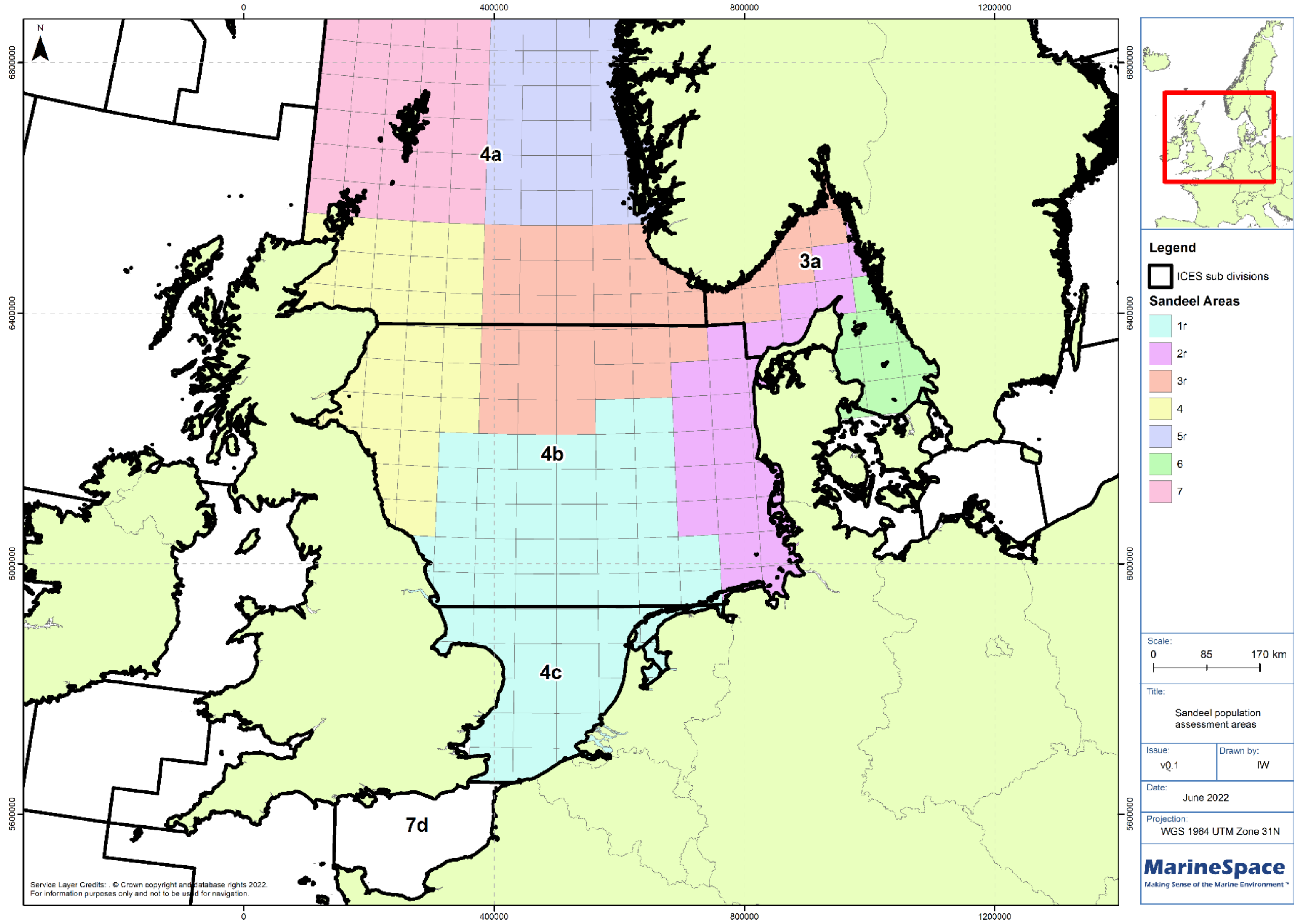
A.1 ICES Areas, Subareas, and Divisions for Sandeel Fisheries

This section describes the compartmentalisation of The Greater North Sea by ICES, and describes the relationship between Areas, Subareas, and Divisions from which sandeel stock data is assessed. Appendix A is supplementary information for Section 2.2.1 of the methodology report.

The International Council for the Exploration of the Sea (ICES) has divided European seas into Areas, Subareas, and Divisions for fisheries data collection and management. These classes can become confusing when comparing to one another, or other primary sources of data, especially when referring to species-specific Areas such as ICES Sandeel Areas 1r-7r. 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 sandeel stocks in the Greater North Sea, Skagerrak, and the east English Channel are 4a-b, 3a, and 7d (Figure A1).

In the case of sandeel species, ICES has divided The Greater North Sea into 7 sandeel-specific Areas (Figure A1) that do not align with the standard ICES Subareas and Divisions. It is important to note the difference, as ICES sandeel stock reports labelled 'Divisions 4b-c, Sandeel Area 1r' are referring only to the sandeel stocks in Sandeel Area 1r, which does not represent the total spatial extent of Divisions 4b-c (Figure Y).

Figure A1: The spatial extents and overlaps between ICES Divisions (4a-c, 3a, and 7d) and ICES Sandeel Areas (1r-7r), 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

International Council for the Exploration of the Sea (ICES), 2017. Report for the benchmark on sandeel (WKSand 2016), 31 October – 4 November 2016, Bergen, Norway. ICES CM 2016/ACOM: 33: pp. 319.

Appendix B

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

This updated method statement includes aspects of the methodology described in Latto *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 (Latto *et al*., 2013) methods, and associated IP, carried over into this updated method statement are explicitly identified within the relevant sections.

B.1 Sediment Classification to Enable Determination of Sandeel 'Preferred' and 'Marginal' Habitat

Lesser Sandeel *Ammodytes marinus* display a strong diurnal cycle, occupying a position in the water column during the day where they feed on plankton in schools, before retreating into the seabed at night or when threatened (Freeman *et al.*, 2004). This behaviour limits the habitat that sandeel can occupy to areas of very specific sediment particle sizes, where penetration into the sediment is possible.

Numerous studies have investigated the sediment preferences of sandeel species, identifying consistent habitat requirements (Macer, 1966; Reay, 1970; Wright *et al.*, 1998; Wright *et al.*, 2000; Holland *et al.*, 2005; van der Kooij *et al.*, 2008; Greenstreet *et al.*, 2010). Wright *et al.* (2000) and Holland *et al.* (2005) described sandeel habitat requirements as medium to coarse sand of a diameter between 0.25 and 2 mm, with a mud content of less than 10% (particles < 63 µm). Wright *et al.* (2000) demonstrated this range in a series of controlled laboratory-based experiments and the results were replicated in field observations by Holland *et al.* (2005).

Greenstreet *et al.* (2010) investigated the determinations made in Holland *et al.* (2005) and presented an alternative analysis. These two studies reviewed and reconsidered all the previous work on sandeel habitat preference (as cited above). Therefore, the basis for determining preferred and marginal sandeel habitat used in this methodology is derived from the Holland *et al.* (2005) and Greenstreet *et al.* (2010) investigations.

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.

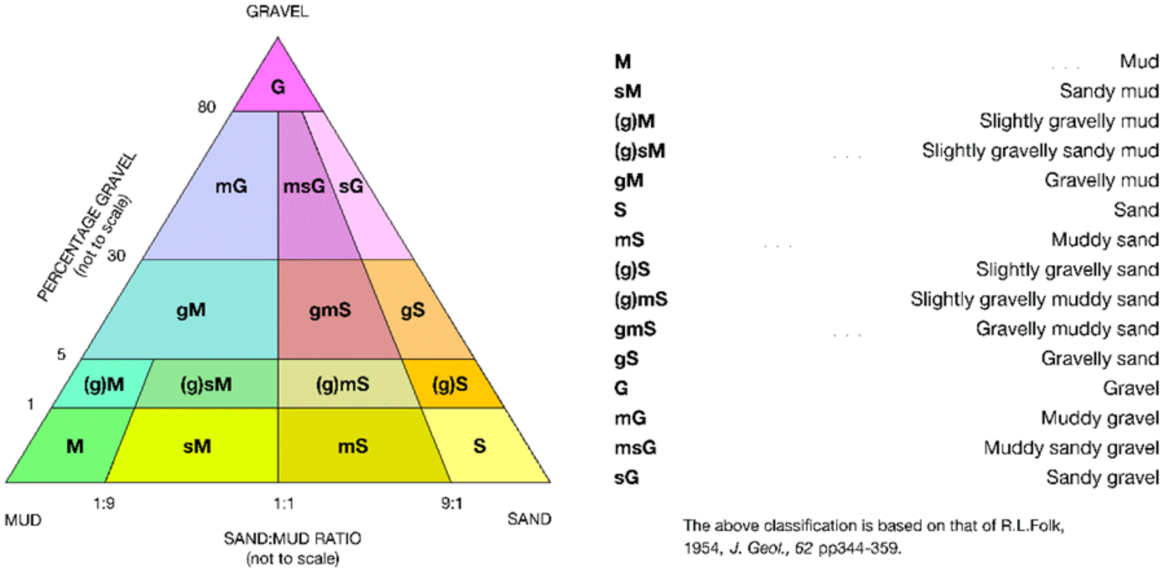
Table B1: Wentworth particle size descriptions (From: Wentworth, 1922)

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		

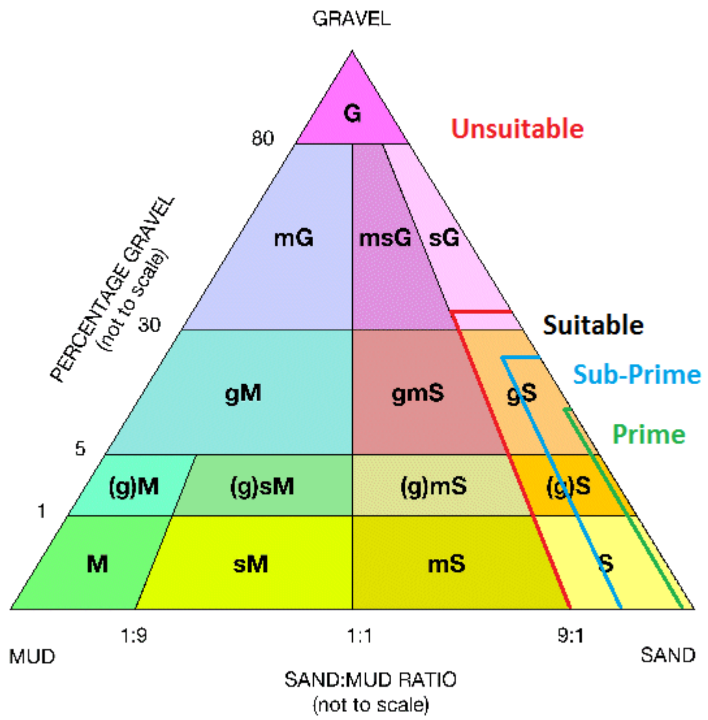
Figure B1: The Folk triangle and description of sediment codes. (From: Folk, 1954)



Describing the sediments in terms of the Wentworth (1922) scale Holland *et al.* (2005) identified prime to suitable[1] sandeel habitat (0.25 and 2 mm, with a mud content of less than 10%) and included the fractions very coarse sand, coarse sand and medium sand. Identifying this range on the BGS modified Folk (1954) triangle proves complex. This is because the Sand descriptor on the triangle also includes fine and very fine sand as per the Wentworth (1922) scale and these have been shown to be negatively associated with sandeel abundance (Holland *et al.*, 2005). Despite this discrepancy, it is still possible to indicate where the habitat indicated in Holland *et al.* (2005) lies within the Folk triangle (Figure B2). It is apparent from Figure B2 that the prime habitat for sandeel covers a very small proportion of the Sand, slightly gravelly Sand and gravelly Sand divisions, whereas the region determined as suitable habitat includes the whole of these divisions and a small proportion of sandy Gravel (<35% gravel).

[1] See the Glossary of terms for the definition used in this method statement of Preferred, Prime, Sub-Prime, Suitable and Unsuitable sandeel habitat.

Figure B2: Sediment suitability for sandeel habitat (Source: Folk, 1954; Holland *et al*., 2005)

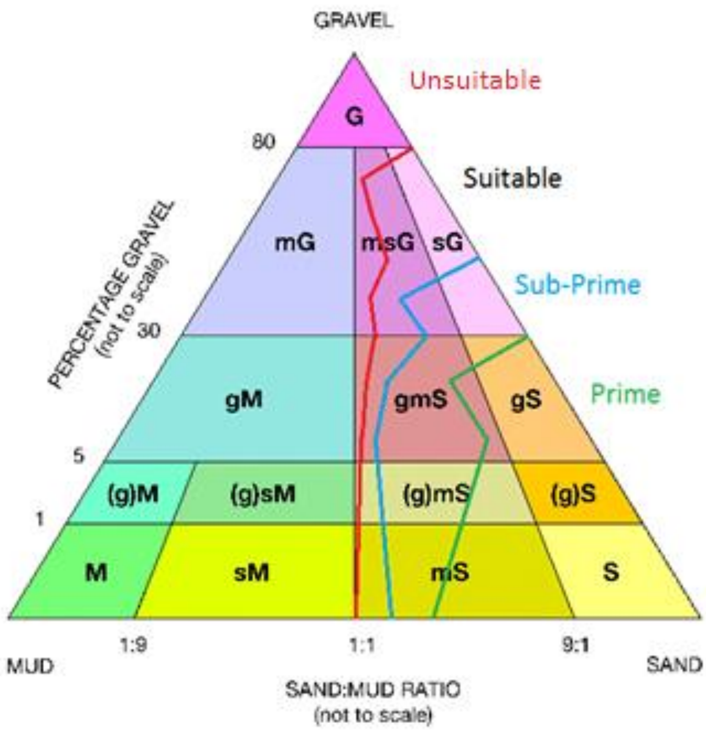


Greenstreet *et al.* (2010) reinterpreted the data contained in Holland *et al.* (2005) and grouped the very fine and fine sands together with the silts and clay (Table B3). By doing so they were able to interpret the division of habitat suitability in relation to the percentage of coarse sands compared to mud (mud measured as <0.25 mm). By grouping fine sands with mud, it was then possible to plot the representative habitats onto the Folk triangle (Figure B3). It is important to note that in Figure B3 the fine sands are grouped with the mud and therefore this is not a representation of the BGS modified Folk classification nor does it relate to the available EMODnet Folk 16 seabed sediment map.

Table B3: The division of Folk sediment classifications based on information presented in Greenstreet *et al.* (2010) in relation to the Wentworth (1922) particle size scale. (Source: Wentworth, 1922; Folk, 1954; Greenstreet *et al.*, 2010)

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	Mud
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		

Figure B3: The suitability of sediments for sandeel habitat based on information provided in Greenstreet et al. (2010) (Source: Folk, 1954; Greenstreet *et al.*, 2010)



Reviewing both the Holland *et al.* (2005) and the Greenstreet *et al.* (2010) interpretations of the sediment data (as indicated on the Folk triangles of Figure B2 and Figure B3), a sandeel preferred and marginal habitat classification has been identified (Figure B4). This classification utilises the BGS modified Folk classification (Table B2) and has the intention of applying the results to the 1:250,000 scale seabed sediment maps. Greenstreet *et al.* (2010) included components of the muddy Sands within their prime, sub-prime and suitable habitat classification (Figure B3). However, when using the EMODnet seabed sediment map the division across the muddy Sands divisions cannot be made to effectively show the Mud to Sand ratio. If the methodology adopted to map the muddy Sand divisions this would result in a gross over-representation of sandeel preferred habitat (much more so than the mapping of sandy Gravels as discussed below).

By restricting the mud content of the sediments to no more than 10%, as in Holland *et al.* (2005) (they excluded muddy Sands from their selection of prime, sub-prime and suitable habitats for sandeel (Figure B2)), it is possible to limit the selection to the right hand side of the Folk triangle. This approach has been adopted in this methodology. Therefore, the Holland *et al.* (2005) habitat consideration, excluding divisions containing more than 10% mud, has been adopted, whilst the Greenstreet *et al.* (2010) conclusion has been rejected.

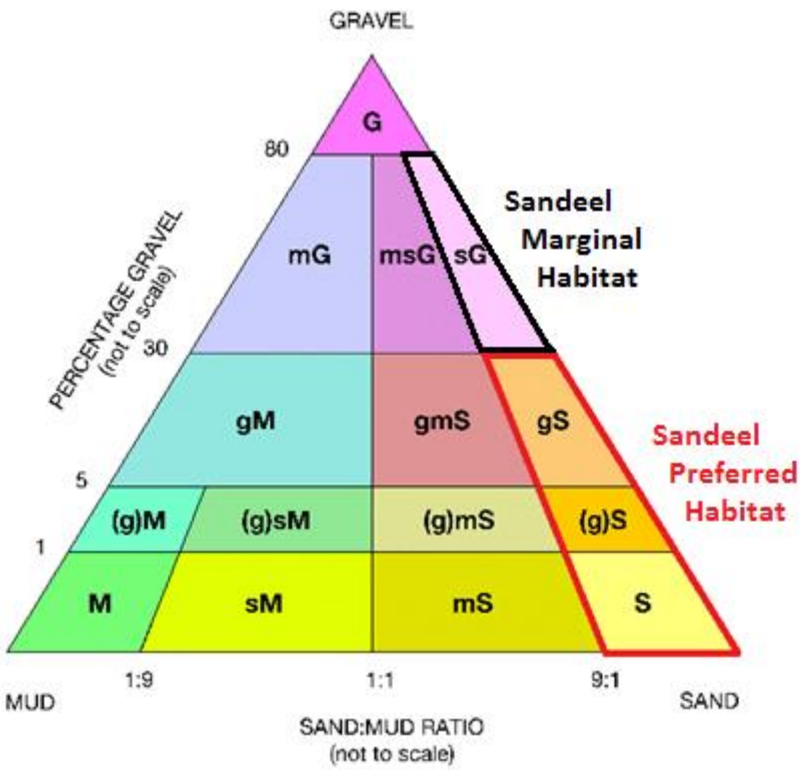
The Sand, slightly gravelly Sand and gravelly Sand divisions of the Folk classification are considered to represent sandeel preferred habitat i.e. the sediment divisions which sandeel favourably select as habitat.

Holland *et al.* (2005) and Greenstreet *et al*. (2010) also concluded that suitable sandeel habitat can include a gravel component. Greenstreet *et al*. (2010) identified the prime habitat as containing less than 30% gravel and the sub-prime habitat with a gravel component greater than 30% but less than 50%. They gave the boundary between suitable and unsuitable habitat as 80% gravel (Figure B3). Holland *et al.* (2005) described the threshold for sub-prime habitat as 25% gravel or less with sediment containing more than 35% gravel as unsuitable (Figure B2). Comparing the Holland *et al.* (2005) and Greenstreet *et al*. (2010) determinations it is apparent that there is a discrepancy between the respective classifications falling within/across the Folk (1954) sandy Gravel division. In the Folk classification gravel content greater than 30% and up to 80% is represented by the sandy Gravel division (with a 10% or less mud component). Using this classification there is an inability to divide the sandy Gravel division at the 35% or 50% level in the Folk classification. Therefore, any representation of sandy Gravel (using the EMODnet maps) will include the Greenstreet *et al*. (2010) classification of suitable habitat. However, the sandy Gravel division will also map a large component of unsuitable habitat as determined by Holland *et al.* (2005).

Whilst it is acknowledged that mapping sandy Gravel may over-represent sandeel habitat, as the 35% gravel content cannot be determined, a precautionary approach has been adopted. As Greenstreet *et al*. (2010) include 50-80% component within their suitable habitat category then this methodology uses the sandy Gravel division. However, this is determined to be marginal habitat i.e. it is sandeel habitat with adequate sediment structure but will only support low numbers of sandeel.

Therefore, the resulting sandeel habitat classification used for this methodology is represented by the Sand, slightly gravelly Sand and gravelly Sand divisions (preferred habitat) and sandy Gravel (marginal habitat) of the Folk (1954) triangle (Figure B4).

Figure B4: Folk triangle with preferred and marginal sandeel habitat indicated. (Source: Folk, 1954; Holland *et al.*, 2005; Greenstreet *et al.*, 2010)



B.2 References Explicitly Reviewed for Habitat Classification

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Appendix C

This updated method statement includes aspects of the methodology described in Latto *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 sandeel potential supporting habitat or the '*Sandeel 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 habitat likely to support sandeel include:

- Substrate Folk Classification: European Marine Observation and Data Network (EMODnet);
- Substrate Folk Classification: OneBenthic Macrofaunal Assemblages;
- Fishing Fleet: Vessel Monitoring Systems (VMS);
- Spawning Grounds: Eastern Sea Fisheries Joint Committee (ESFJC);
- Spawning Grounds: Coull *et al.* (1998);
- Spawning Grounds: Wright *et al.* (2019);
- Spawning Grounds: OneBenthic Sandeel Presence.

In all cases, the data inform the potential location of potential supporting habitat for sandeel. 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 (Kyle-Henney *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 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); and the Marine Aggregate Regional Environmental Assessments (MAREAs) include REC data Therefore 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 (Latto *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 (WG) 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 Habitat	Suitability of the dataset to inform potential supporting habitat	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/sandeel habitat, 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 Potential Supporting Habitat for Sandeel

The final parameter, 'indicator of habitat', is not concerned with the data themselves, but the confidence in the data's ability to indicate supporting habitat for sandeel 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 supporting habitat? As this project is using the data to assess the likelihood or confidence of supporting habitat 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 supporting habitat. This was only concerned with parameters that reduced certainty about the data so, for example, fishing time (VMS) does not reduce certainty in the data. For example, with abundance, either there is supporting habitat 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 (Section C.2).

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 supporting habitat, a score of 0 would mean it is unknown whether the dataset can be used to infer supporting habitat 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 supporting habitat = 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 supporting habitat for sandeel. The confidence in the data is scored and justified within the first five parameters in Table C3.

Table C3: EMODnet Folk Map Confidence Scores

Confidence test	Score	Rationale - Please explain scoring with reference to all considerations
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. EMODnet data is 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 Habitat*	2 or 0	See Table C5 below. Varies by Folk class category, Folk class boundary representation.

*For the indicator of habitat, a score of 0 would mean it is unknown whether the dataset can be used to infer supporting habitat 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 habitat = very low confidence.

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

C.2.1.2 Confidence in the EMODnet Data Indicating Potential Supporting Habitat for Sandeel

As detailed in the methodology report, sandeel are known to prefer Sand, slightly gravelly Sand and gravelly Sand; and also to have a marginal habitat preference within sandy Gravel. Therefore, the Folk sediment class provides a spatially variable indicator of potential supporting habitat and hence a level of confidence.

However, the level of confidence in the Folk classes indicating potential supporting habitat for sandeel 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 Sand, slightly gravelly Sand and gravelly Sand indicating potential supporting habitat for sandeel (hence the 'preferred habitat'), than sandy Gravel (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 supporting habitat for sandeel. E.g. the Folk category Sand is suitably defined for sandeel, i.e. sandeel preferred habitat is within the whole of the Sand class, whereas Gravel contains sediment types outside of the preferred range for Atlantic herring spawning and therefore has a lower confidence (Kyle-Henney *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 potential supporting habitat for sandeel, 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 potential supporting habitat for sandeel with high confidence, as it is only an indicator. Direct measurements of supporting habitat, such as OneBenthic Sandeel Presence data, carry much greater confidence. Therefore, the matrix is scored from 0 to 2. As detailed above, where scoring the indicator for supporting habitat, 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 Sandeel

As per the method statement for sandeel, of the four Folk categories that represent potential habitat for sandeel (sandy Gravel, gravelly Sand, slightly gravelly Sand and Sand), one of these over-represents the category: sandy Gravel. This reduces the confidence. Also, the greatest preference for habitat is at the sandy end of the scale. This increases the confidence. Therefore, the matrix results are as follows (Table C5):

Table C5: Sandeel 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)	sG = 0 (very low)	N/A
Folk category indicates preferred habitat = 2 (medium)	N/A	gS, (g)S, S = 2 (medium)

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 Taxa Search 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 1 mm 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 (Sand (S), slightly gravelly Sand ((g)S) and gravelly Sand (gS) sediment classes) and marginal (sandy Gravel (sG) sediment class) potential supporting habitat for sandeel are represented by the faunal assemblages in Table C6, associated with slightly gravelly Sand ((g)S), gravelly Sand (gS), and sandy Gravel (sG). It is noted that the preferred Sand (S) 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 will be 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	Marginal
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	Marginal
B1b	2	54	44	V(m)gS	sG	0.44	Marginal
C1a	5	46	49	(m)sG	sG	0.9	Marginal
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	Preferred
D2b	17	77	6	(g)(m)S	gmS	1.05	Unsuitable
D2c	4	84	12	V(m)(g)S	gS	1.15	Preferred
D2d	3	93	4	V(g)v(m)S	(g)S	0.82	Preferred

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 Supporting Habitat	3	Direct indicator of preferred (excluding Sand) and marginal 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 supporting habitat, 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 Habitat	0	The demersal gears target sandeel as well as many other species; and provide a low confidence indicator to habitat. Sandeel have limited mobility and are fished year-round, therefore any fishing activity with these gear types may target sandeel. With the exception of industrial trawlers (Sandeeler) these gears are likely to be targeting a number of species and may not be targeting sandeel at all. Therefore, excluding Sandeelers, there is low confidence in this data as an indicator of potential spawning sandeel.

C.2.3.2 Confidence in the VMS Data Indicating Atlantic Herring Potential Spawning Grounds and Sandeel Habitat

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 supporting habitat. As one gear type will target a number of species and not just sandeel, the probability of it informing potential supporting habitat is very low. A full justification is provided in Table C8. However, in summary, demersal gears are an indicator of potential supporting habitat for sandeel, as well as an indication of habitat damage and/or deterioration pressure footprints.

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 sandeel 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 Habitat	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 sandeel (where adult sandeel locations are a good indicator of spawning areas), 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 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 Habitat	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 in the data-layer as an indicator of habitat.

C.2.5.2 Confidence in the Coull *et al.* (1998) Data Indicating Habitat

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

C.2.6 Wright *et al.* (2019)

The Wright *et al*. (2019) study determined through the modelling of larval transport and otolith chemistry that populations of sandeel greater than 200 km apart can be determined as distinct, non-mixing populations. However, the use of the Wright *et al*. (2019) study within this methodology is restricted to the broadscale chart of fishing grounds displayed in Figure 1 of the Wright *et al*. (2019) publication, as opposed to the resultant figures of the study.

C.2.6.1 Confidence in the Wright *et al.* (2019) Data

The scores for the confidence in the Wright *et al.* (2019) data are provided in the first five parameters of Table C11. 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 C11: Wright et al. (2019) Spawning Grounds Confidence Scores

Confidence test	Score	Rationale
Method	1	Data are based on collated ICES fisheries data. However, no detail is provided as to the data's robustness or age, and it is not clear how the maps have been compiled. However, it is stated that the data are sourced from a reputable source (ICES) 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	3	Report published in 2019 and so data are present - it is stated that the map should not be considered as a rigid boundary, based on the findings of the publication.
Positioning	2	As no method has been provided for how the boundary of spawning areas was produced, accuracy is not known. However, the boundaries define ICES stocks used in assessment, and therefore a reasonable accuracy can be determined.
Coverage	2	The map appears to cover all of the North Sea (as relevant to the population scale of this methodology). The coverage is down-graded however, due to a lack of coverage along the UK's eastern and southern coasts (decreasing relevance at the regional scale, apart from the Humber region). There is no information provided on density of points to inform the maps. As noted above, it is stated that the map should not be considered as a rigid boundary.
Quality Standards	0	No evidence of any quality standards.
Indicator of Habitat	2	It is possible that no inference between actual data points is made and is direct mapping of habitat. However, methods do not qualify this and only indicate, reducing confidence in the data-layer as an indicator of habitat.

C.2.6.2 Confidence in the Wright et al. (2019) Data Indicating Habitat

Whilst the Wright et al. (2019) layer has specifically been developed to show potential supporting habitat for sandeel, the methods reported do not detail what types of data were used, lowering the confidence.

C.2.7 OneBenthic Sandeel Presence Data

The OneBenthic Sandeel Presence data is a subset of the grab/core sample dataset, and can be supplied in a point format from the Cefas Open Science OneBenthic portal, specifically the Taxa Search Tool.

Data extracted from this tool identifies all sandeel records from the OneBenthic grab/core dataset. Simple filtering of this data enables any species of interest to be isolated, alongside the coordinates of the sample site and the details of the survey in which the samples were collected. The term 'sandeel' within this assessment primarily includes Greater sandeel *Hyperoplus lanceolatus*, Lesser sandeel *Ammodytes tobianus*, and Raitt's sandeel *Ammodytes marinus*; however evidence suggests the presence of, the less common, Corbin's sandeel *Hyperoplus immaculatus* and smooth sandeel *Gymnammodytes semisquamatus* (Wheeler *et al*., 1978). As such, the OneBenthic data was filtered by the following search terms: 'Ammodytes', 'Ammodytes tobianus', 'Ammodytidae', 'Ammodytes marinus', 'Hyperoplus lanceolatus', 'Hyperoplus immaculatus', and 'Gymnammodytes semisquamatus'.

As a by-product of a 'big data' approach, the sandeel presence data is collected from multiple surveys over a long time series, in which the surveys themselves may not have targeted sandeel specifically. In addition, sandeel are not always represented by beam trawl samples due to their ability to dive into burrows and escape the net. As such, the sandeel presence dataset is assumed to underrepresent the location of sandeel, as beam trawls may pass over sandeel habitat without collecting specimens. This reduction in precision of the data-layer in comparison to real potential supporting habitat for sandeel will result in a lower confidence than would be expected for a direct sampling method. Where sandeel specimens are collected, these locations are a direct indicator of sandeel supporting habitat, and thus carry weight within the methodology, despite the sampling method caveat.

As this dataset consists of point data, a degree of interpolation is required to produce a polygon for use within the heat map. The underrepresentation of sandeel presence that occurs with point sampling will likely reduce with interpolation and increases the 'useability' of the data-layer, albeit with a caveat. 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.

C.2.7.1 Confidence in the OneBenthic Sandeel Presence Data

The scores for the confidence in the OneBenthic Sandeel Presence data are provided in the first five parameters of Table C12.

Table C12: OneBenthic Sandeel Presence Confidence Scores

Confidence test	Score	Rationale
Method	2	The OneBenthic Sandeel Presence dataset is a 'big data' approach that incorporates beam trawl locations from numerous surveys. Whilst the presence of sandeel in this dataset identifies potential supporting habitat, absence of sandeel does not identify unsuitable habitat.
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 Habitat	2	Direct indicator of potential supporting habitat. However, the underrepresentation of sandeel presence reduces confidence in this data-layer as a precise indicator of potential unsuitable habitat (indicated by sandeel absence within the dataset).

C.2.7.2 Confidence in the OneBenthic Sandeel Presence Data Indicating Spawning Grounds

As the OneBenthic Sandeel Presence data represent direct measurements of sandeel presence, there is no inference, it is direct data on potential supporting habitat, as shown in Table C12. However, caution should be taken when considering the absence of sandeel, as this data-layer underrepresents sandeel presence as a result of the limitations in sampling method.

C.3 Combined Confidence Layer

C.3.1 Summary Individual Layers

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

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 Habitat	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 habitat).
10	Total Normalised Score	Total weighted score divided by maximum weighted score, multiplied by the range (5)
11	2022 Total Normalised Score (Sandeel)	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 Habitat	Total Weighted Score	Total Normalised Score	New Total Normalised Score (Sandeel)
Range from 0 to >>	3	3	3	3	3		3	3	30	**5**	**0.1**
Weight	1	1	1	1	1			5			
OneBenthic Macrofaunal Assemblage	3	2	3	2	3	MarineSpace	2.8	3	29	**4.8**	**0.25**
OneBenthic Sandeel Presence	2	3	3	3	3	MarineSpace	2.8	2	24	**4**	**0.25**
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	**1.5**	**0.75**
Wright *et al.* (2019)	1	3	2	2	0	MarineSpace	1.6	2	18	**3**	**0.5**
EMODnet Preferred	2	3	3	3	3	MarineSpace	2.8	2	24	**4**	**0.25**
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 0-3 (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 0-3 (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 supporting habitat.

A single score is next provided for the confidence in the layer indicating potential supporting habitat for sandeel (item 8). This test results in a score of 0-3.

The Total Weighted Score then combines all the scores together for sandeel (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 0-5 (i.e. by dividing by the total possible score of 30 and multiplying by the range, 5). These values could have ranged 0-3 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 (Latto *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 potential supporting habitat for sandeel, 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 OneBenthic ICES sub-rectangle classifications. The spreadsheets showing the above information are also made available.

Table C16: Example of Combined Confidence Score for Sandeel

Parameter	GIS Attribute Name	Value
VMS fishing fleet	VMS	0.75
Coull *et al*. (1998)	Coull *et al*.	0.75
Wright *et al*. (2019)	Wright *et al*.	0.5
ESFJC Sandeel	ESFJC	0.5
OneBenthic Sandeel Presence	OBSP	0.25
EMODnet Preferred	EMODnet_Pref	0.25
Combined score	TOTAL	0.0044
Simplified combined score	CONF_TOTAL	High

C.4 References Explicitly Reviewed for the Confidence Assessment Overview

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