GREENLINK
MARINE ENVIRONMENTAL STATEMENT- WALES

APPENDIX E

Herring Spawning and Sandeel Assessment

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Greenlink Interconnector
- connecting the power markets
in Ireland and Great Britain

Greenlink
INTERCONNECTOR

Co-financed by the European Union
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1. Introduction

This document presents work associated with analysing and mapping the potential spawning habitat resource for herring and sandeel species habitat in relation to the Greenlink Interconnector cable for both UK and Irish waters. The species considered are:

- Atlantic herring *Clupea harengus* Linnaeus, 1758;
- greater sandeel *Hyperoplus lanceolatus* Le Sauvage, 1824;
- Corbin's sandeel *H. immaculatus* Corbin, 1950;
- the lesser sandeel *Ammodytes tobianius* Linnaeus, 1758;
- Raitt's sandeel *A. marinus* Raitt, 1934; and
- the smooth sandeel *Gymnammodytes semisquamatus* Jourdain, 1879.

The work uses the methodology for the Atlantic herring preferred and marginal habitat resource mapping that was conducted and reported in MarineSpace *et al.* (2013a), using the same methods and types of data layers developed for the 2013 mapping exercise (Reach *et al.* 2013).

The same exercise is applied for sandeel preferred and marginal habitat mapping, using the resource mapping methodology (MarineSpace *et al.* 2013b), using the rationale developed by (Latto *et al.* 2013). The process for mapping sandeel habitat is the same as for Atlantic herring with the exclusion of the use of International Herring Larvae Survey (IHLS) data.

The 2013 reports are fundamental to the work presented in this report and should be referenced regarding processes associated with the rationale and detailed methodologies used. Where relevant, specific sections of the 2013 reports are cross-referenced to facilitate easy use and understanding of this report.

1.1 Habitat Resource Parameterisation

The habitat resource data used in the 2013 baseline mapping have been re-visited and updated with post-2012 data (where these are available). The revised baseline was developed in early January 2019, any relevant data available to that point have been considered and used to validate regional scale data.

1.1.1 Spawning Ground Data

The 2013 analyses used the spawning area data and maps from Coull *et al.* (1998) as one of the indicator layers used in the assessment. Subsequent to publication of the 2013 baseline report (MarineSpace Ltd *et al.* 2013a) new fish spawning analyses have been presented by Ellis *et al.* (2012).

Analysis of the Ellis *et al.* (2012) data and maps (by MarineSpace scientists) has demonstrated that the report brings no more useful resolution of data to the

assessment compared to that already incorporated into the assessment from Coull *et al*. (1998). In explanation: the Atlantic herring spawning area maps presented in Ellis *et al*. (2012) replicate the Coull *et al*. (1998) spawning areas and then overlays a time series of IHLS data on top of these areas. The Reach *et al*. (2013) method also does this i.e. the 2013 baseline maps used the Coull *et al*. (1998) spawning areas and then mapped over these with the distribution of the IHLS data used in the assessment.

Therefore, in effect, the 2013 resource mapping exercise and this updated assessment are presenting the same data analysis used by Ellis *et al*. (2012) (e.g. Coull *et al*. (1998) spawning areas and IHLS data). The same extrapolation of spawning area is being presented, with the benefit that the data layers can be assessed separately. In fact, this method allows the incorporation of post-2011 IHLS data making it a more 'up-dateable' process than just relying upon the Ellis *et al*. (2012) data. For this reason, the data vintage score for the Coull *et al*. (1998) data is not adjusted and both these data and the updated IHLS data can be considered to present the same information as the Ellis *et al*. (2012) data.

1.1.2 Fishing Fleet and Vessel Monitoring System Data

At the time of the 2018 assessment only **Vessel Monitoring System (VMS) data** from 2013-2016 were available in addition to the 2002-2011 baseline assessed as part of the 2013 exercise (MarineSpace *et al*. 2013a, 2013b). This assessment therefore considers VMS data 2002-2016.

VMS data only provide differentiation between fishing locations by gear types, and therefore it is the gear types that have been used to inform habitat resource areas. As one gear type will target a number of species and not just Atlantic herring or sandeel spp., the probability of it informing spawning grounds or habitat is very low (see Section 1.2 of this report; Section 2.5 of MarineSpace *et al*., 2013a, 2013b and Appendix B of those reports).

However, pelagic gears are considered an indicator of Atlantic herring spawning areas; and demersal gears are an indicator of sandeel habitat as well as an indication of habitat damage and / or deterioration pressure footprints for both species groups.

The confidence in the VMS data remains the same as for the original 2013 assessments (low; MarineSpace *et al*. 2013a) (see Section 1.2).

Wales and Ireland Sea Fishing Atlas - The Sea Fishing Atlas for Wales was compiled by the then Countryside Council for Wales (CCW) (now part of Natural Resources Wales(NRW)) in 2010 from information collected between 2000 and 2005 from various sources including fishermen, fishery officers and fishery regulators, and other marine users.

The Cefas Inshore Fishing Activity – Trawling Activity – data layer remains the same as for the 2013 baseline assessment e.g. 2010-2012; as no updated data were identified to inform the revised assessment.

The data vintage score has been revisited and adjusted (down-scored) to reflect the age of the data as considered in the revised baseline assessment. However, the lowering of the confidence in data vintage score (from 3 down to 2) has not affected the overall data confidence associated with this data layer (see Section 1.2 of this report; Section 2.5 of MarineSpace *et al.* 2013a, 2013b and Appendix B of those reports).

1.1.3 Data used in the 2018 Baseline Assessment

The 2018 maps were produced by integrating the 2013 baseline data layers with the appropriate new data. Table 1-1 presents the data layers used to build the 2018 'heat' maps.

Table 1-1 Data layers used to produce the habitat resource 'heat' maps

Data classification	Data	Information
Atlantic herring		
Seabed Sediment	British Geological Survey	Herring **preferred** sediment polygon regions
Seabed Sediment	British Geological Survey	Herring **marginal** sediment polygon regions
Spawning Ground	Coull *et al.* (1998)†	Herring Spawning beds
Fishing Fleet	Marine Management Organisation (MMO) Vessel Monitoring System	2013-2016 for Pelagic Fishing Activity
Fishing Fleet	Natural Resources Wales (NRW)	Wales Sea Fishing Atlas data from 200-2005
Fishing Fleet	Cefas Inshore Fishing Activity	2010-2012 Trawling Activity
Sandeel species		
Seabed Sediment*	British Geological Survey	Sandeel **preferred** sediment polygon regions
Seabed Sediment*	British Geological Survey	Sandeel **marginal** sediment polygon regions
Spawning Ground	Coull *et al.* (1998)†	Sandeel Spawning
Fishing Fleet	MMO Vessel Monitoring System	2013-2016 for Demersal Fishing Activity
Fishing Fleet	NRW	Wales Sea Fishing Atlas data from 200-2005
Fishing Fleet	Cefas Inshore Fishing Activity	2010-2012 Trawling Activity
Fishing Fleet	Ellis *et al.* (2012)¥	High and low intensity fishing activity and relationship with spawning grounds

* adjusted Folk Classification; † Coull, K.A., Johnstone, R., and S.I. Rogers. 1998. Fisheries Sensitivity Maps in British Waters. Published and distributed by UKOOA Ltd; ¥Ellis J.R., Milligan S.P., Readdy L., Taylor N., and Brown M.J., 2012. Spawning and nursery grounds of selected fish species in UK waters. *Sci. Ser. Tech. Rep.*, Cefas Lowestoft, 147, 56 pp.

An additional datum layer was also used to 'sense check' the British Geological Survey (BGS) seabed surface sediment data:

- Particle Size Analysis (PSA) data collected from the Greenlink Interconnector route (MMT 2019).

The PSA data were analysed, classified and collated in relation to the 2013 Atlantic herring potential spawning habitat, and sandeel optimal habitat classifications, using the Folk (1954) sediment classification (Table 1-2; Figure 1-1; Table 1-3; Table 1-4; Figure 1-2)

Table 1-2 Description of Atlantic herring potential spawning habitat sediment classes

Preferred habitat sediment class	In the context of this methodology these are the sediment divisions / units represented by Gravel and sandy Gravel which Atlantic herring favourably select as part of their spawning habitat requirements. It should be noted that other physical, chemical and biotic factors contribute to the overall definition of potential spawning habitat
Marginal habitat sediment class	In the context of this methodology this is the sediment division / unit represented by gravelly Sand which Atlantic herring may select as part of their spawning habitat requirements. This sediment class has adequate sediment structure but is less favourable than preferred habitat
Unsuitable habitat sediment class	Seabed sediment classes which have inadequate sediment structure to be chosen by Atlantic herring for spawning grounds

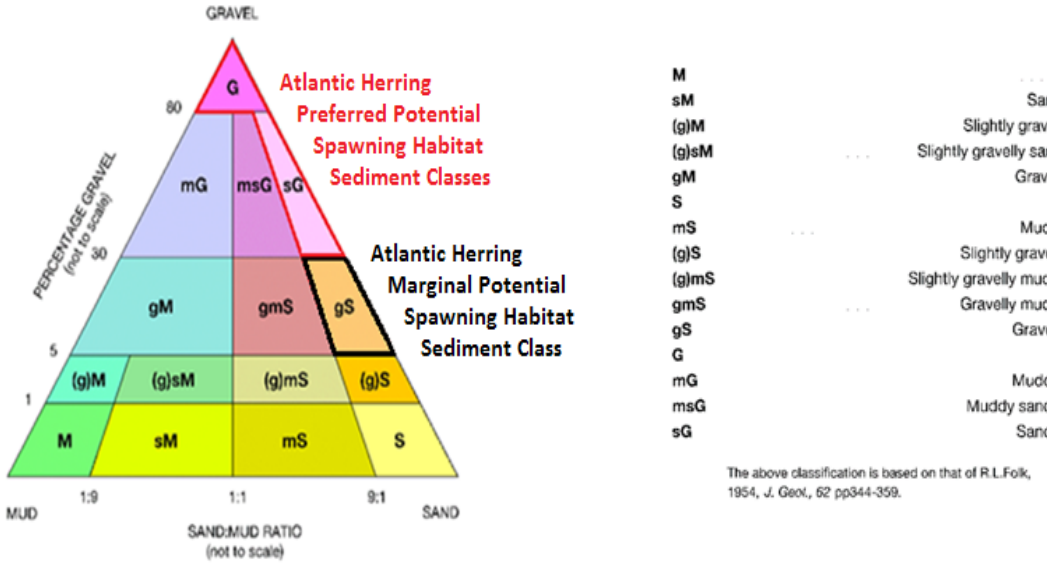
Source: Appendix A in MarineSpace Ltd *et al*. 2013a; Folk 1954

Table 1-3 The partition of Atlantic herring potential spawning habitat sediment classes

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

Source: Appendix A in MarineSpace Ltd *et al*. 2013a; Folk 1954

Figure 1-1 The Folk sediment triangle with Atlantic herring preferred and marginal habitat sediment classes indicating potential spawning habitat



Note: It is important to note that the Folk (1954) sediment classes over-represent the suitability of an individual class to completely represent sediment habitat that will be used by Atlantic herring for spawning. This is due to the percentage of muds component within the sediment divisions. However, without a complete re-working of all the BGS data used in developing the 1:250,000 scale sediment maps a direct representation of the <5% muds (<63 µm) is not possible. The Marine Management Organisation (MMO) and MMO Regulatory Advisory Group (RAG) agreed that such an exercise is beyond the requirements of any specific EIA (as required under The Marine Works (Environmental Impact Assessment) Regulations 2007 (as amended)). Therefore, the best-fit Folk sediment classification, presented in amended form as Figure 1-1, has been used to conduct the assessments within this report.

Source: Appendix A in MarineSpace Ltd *et al.*, 2013a; Folk 1954

Table 1-4 Description of sandeel species habitat sediment classes

Preferred habitat sediment class	In the context of this methodology these are the sediment divisions / units represented by Sand, slightly gravelly Sand and gravelly Sand which sandeel favourably select as part of their habitat requirements. It should be noted that other physical, chemical and biotic factors contribute to the overall definition of potential spawning habitat
Marginal habitat sediment class	In the context of this methodology this is the sediment division / unit represented by sandy Gravel which sandeel may select as part of their habitat requirements. This sediment class has adequate sediment structure but is less favourable than preferred habitat
Unsuitable habitat sediment class	Seabed sediment classes which have inadequate sediment structure to be chosen by sandeel

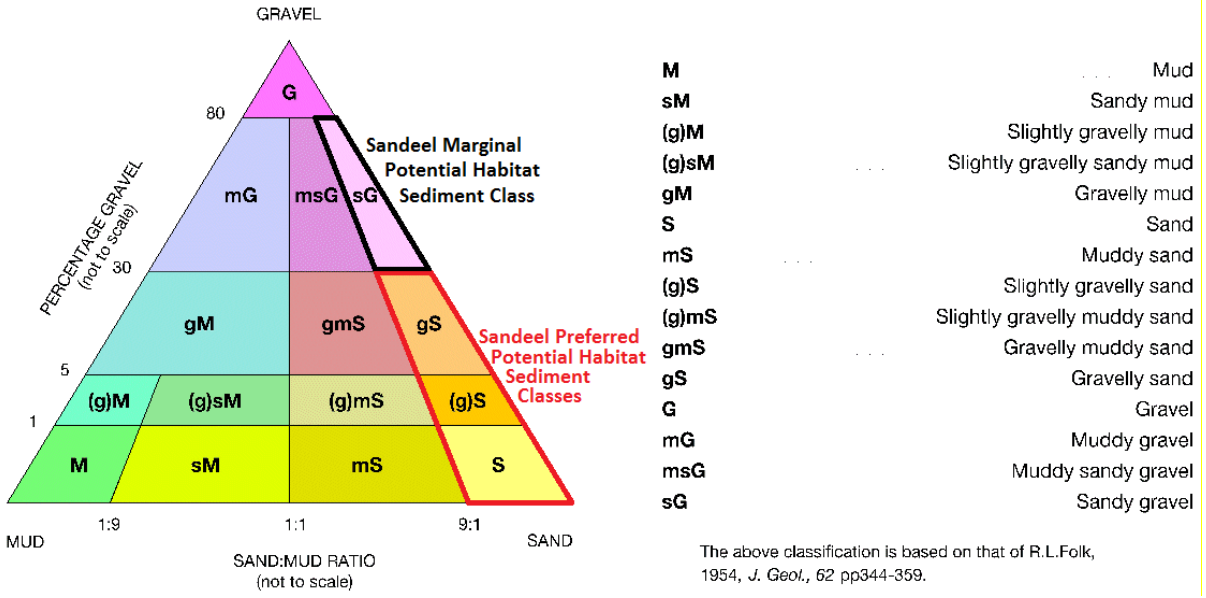
Source: Appendix A in MarineSpace Ltd *et al.* 2013b; Folk 1954

Table 1-5 The partition of sandeel species habitat sediment classes

% Particle contribution (Muds = clays and silts <63 µm)	Folk sediment unit	Habitat sediment classification
<1% muds, >85% Sand	Part Sand, part slightly gravelly Sand and part gravelly Sand	Preferred
<4% muds, >70% Sand	Part Sand, part slightly gravelly Sand and part gravelly Sand	Preferred
<10% muds, >50% Sand	Part gravelly Sand and part sandy Gravel	Marginal
>10% muds, <50% Sand	Everything excluding Gravel, part sandy Gravel and part gravelly Sand	Unsuitable

Source: Appendix A in MarineSpace Ltd *et al.* 2013b; Folk 1954

Figure 1-2 The Folk sediment triangle with sandeel species preferred and marginal habitat sediment classes



Source: Appendix A in MarineSpace Ltd *et al.* 2013b; Folk 1954

All data sets were acquired in a polygon format (area of spatial extent), rather than point, line or raster / gridded data, as this allowed them to be combined (union tool in GIS) and result in an overall assessment.

1.2 Data Confidence Assessment

All data were subjected to the data confidence assessment process developed in 2013 (Appendix B in MarineSpace Ltd *et al*. 2013a, 2013b). It is important to note that any data unchanged since used for the 2013 baseline were also re-assessed as data vintage is one of the confidence parameters assessed. All data were 'tagged' with the appropriate confidence score ready for 'heat' mapping.

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

The data confidence scores for each data layer are presented in Table 1-6.

Data vintage has been considered for those datasets not updated with additional data since the 2013 baseline was reported.

Table 1-6 Data layer confidence assessment scores

Atlantic herring		
Data classification	**Data**	**Confidence assigned to layer**
Seabed Sediment*	British Geological Survey – 'preferred' habitat	3
Seabed Sediment*	British Geological Survey – 'marginal' habitat	2
Spawning Ground	Coull *et al.* (1998)†	3
Fishing Fleet	Vessel Monitoring System	2
Fishing Fleet	Cefas Inshore Fishing Activity	2
Fishing Fleet	Wales and Ireland Fishing atlas	2
Sandeel species		
Data classification	**Data**	**Confidence assigned to layer**
Seabed Sediment*	British Geological Survey – 'preferred' habitat	4
Seabed Sediment*	British Geological Survey – 'marginal' habitat	2
Spawning Ground	Coull *et al.* (1998)†	3
Fishing Fleet	Vessel Monitoring System	2
Fishing Fleet	Cefas Inshore Fishing Activity	2
Fishing Fleet	Wales and Ireland Fishing atlas	2
Fishing Fleet	Ellis *et al.* (2012)¥ High Intensity	3
Fishing Fleet	Ellis *et al.* (2012)¥ Low Intensity	2

* adjusted Folk Classification; † Coull, K.A., Johnstone, R., and S.I. Rogers. 1998. *Fisheries Sensitivity Maps in British Waters*. Published and distributed by UKOOA Ltd; ¥Ellis J.R., Milligan S.P., Readdy L., Taylor N., and Brown M.J., 2012. Spawning and nursery grounds of selected fish species in UK waters. *Sci. Ser. Tech. Rep.*, Cefas Lowestoft, 147, 56 pp.

It is important to note that the BGS 1:250K seabed surface data have a different confidence score for Atlantic herring compared to sandeel species (Table 1-6).

As an overview, the Folk classification ties in better for sandeel species for preferred habitat type (Sand (S), slightly gravelly Sand((g)S), gravelly Sand (gS) and sandy Gravel (sG) than it does for preferred habitat for Atlantic herring Gravel (G) and sandy Gravel (sG) (see the Folk triangles in Figure 1-1 and Figure 1-2) due to sediment gradings within the Folk classifications. Further information is provided in Section 2.5.5 of both the 2013 Atlantic herring report and the 2013 sandeel report (MarineSpace et al. 2013a, 2013b).

1.2.2 Atlantic Herring

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

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

The habitat can only have a very low or low assessment due to the Folk classification limitations.

1.2.3 Sandeel Species

As per the method statement for sandeel, of the four Folk categories that represent potential sandeel habitat sediment class (Sand (S), slightly gravelly Sand((g)S), gravelly Sand (gS) and sandy Gravel (sG)), **only the marginal habitat sediment sandy Gravel over-represent the habitat divisions. This reduces the confidence in the data layer**. In contrast a greater degree of confidence is placed in the preferred habitat sediments **as these are correctly represented by the Folk category**. Therefore, the matrix results are as follows:

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)

1.2.4 Atlantic Herring Potential Spawning Habitat: Confidence

Intervals of 4 were chosen to develop the categorisation of 'heat' associated with mapping i.e. 1-4, 5-8, 9-12. This ensures that any location with a single layer score of 5 (i.e. IHLS), is not included within the lowest category. Therefore, use of categories of multiples of 4 (e.g. as opposed to 5) allows greater differentiation.

The confidence scores result in a multi-layer range from 2-12 with: 2-4 = 'low' confidence; 5-8 = 'medium'; and 9-12 = 'high' confidence.

1.2.5 Sandeel Potential Habitat: Confidence

Intervals of 4 were chosen to develop the categorisation of 'heat' associated with mapping. The confidence scores result in a multi-layer range from 2-13 with: 2-5 = 'low' confidence; 6-9 = 'medium'; and 10-13 = 'high' confidence.

2. 'Heat' Mapping

Following the data confidence scoring, all data layers were analysed in GIS through multi-layer mapping i.e. the combination of overlapping data layers and the associated confidence score were used to produce the 'heat' maps. The combined confidence is the sum of all layers at any one location. This has been produced by simply adding the score for each layer to a total: the greater the number of overlapping data layers, the higher the probability that the seabed location represents potential habitat.

The 'heat' map is presented using BGS 1:250,000 seabed sediment base-maps. A comparison of those data and the site specific PSA sediment data has been undertaken to determine if the two datasets provide an analogous representation of seabed sediment character (see Section 2.6). The comparison also presents an opportunity to determine any locations where there is poor correlation or a significant separation in the BGS data and the PSA sediment data.

The 'heat map' shows the probability, for any seabed location, of the presence of Atlantic herring potential spawning habitat or sandeel habitat to be present, or for an area to support spawning activity. The maps can be produced at a range of scales from the seas-scale level (e.g. spawning population level) down to the licence area effect footprint scale.

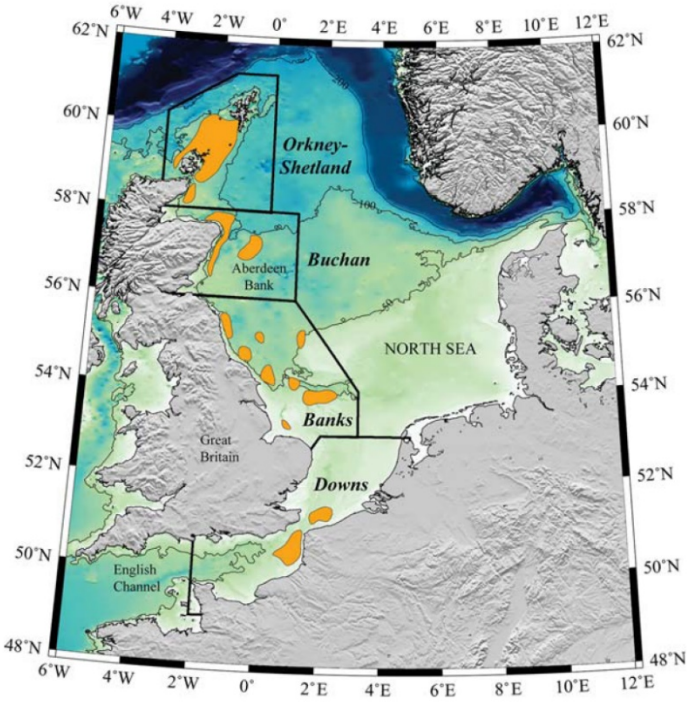
2.1 Atlantic Herring Spawning Population-scale Mapping Results

As previously identified in the 2013 assessments, there are four Atlantic herring spawning populations associated with UK waters in the North Sea and English Channel (Payne 2010; MarineSpace Ltd *et al*. 2013a; ICES 2017) (Figure 2-1):

- Orkney / Shetland;
- Buchan;
- Banks; and
- Downs.

Due to the geographic range of the Greenlink Interconnector route the mapping exercise for potential spawning habitat is not related to any of the main spawning populations within the UK. According to the Coull *et al*. (1998) data there is a small area of herring spawning near the coast of Freshwater West. The sandeel habitat mapping exercise relates to the same study area as the Atlantic herring, although it is not just concerned with mapping spawning habitat, but also habitat used all year round, for all life stages.

Figure 2-1 Distribution of Atlantic herring spawning populations recorded in UK Waters



Source: Payne, 2010; MarineSpace Ltd *et al.*, 2013a; ICES, 2017

In 2009 ICES (International Council for the Exploration of the Seas) adjusted the Irish Box (including ICES rectangles VIIa, VIIb, VIIf, VIIg, and VIIj) to the Biologically Sensitive Area (BSA) (ICES, 2009) Figure 2-2). The BSA includes Atlantic herring with the following statement regarding the importance of the area for the species:

"*Many inshore spawning sites and nursery areas* [are] *within the BSA although the BSA and associated management measures are unlikely to affect the species as controls mostly affect fishing further offshore.*"

Figure 2-2 shows that the BSA lies to the north of the proposed Greenlink route. However, additional advice from ICES (2017), for Herring in Division VIIa South of 52° 30' N and VIIg,h,j,k (Celtic Sea and South of Ireland) states:

"*The stock SSB* [Spawning Stock Biomass] *is estimated to be declining and is estimated as 46 048 t. Mean F*[1] *(2-5 ring) in 2016 is estimated as being 0.40, having increased from 0.07 in 2009. Overall there had been a substantial decrease in F from 0.42 in 2004, but this is increasing again in recent years. Recruitment was good for several years with strong cohorts in 2005, 2007, 2009, 2010, 2011 and*

[1] F = Fecundity (egg-bearing capacity). Mean F = mean Fecundity metric related to adult female fish able to / with the potential to spawn. The term 'ring' relates to age of the fish. Post-egg and up to first year fish are 0-ringers. As the fish goes through annual seasons it lays down seasonal growth rings on the otolith (a statolith laid down in the ear) – 1 bold ring is 1 year old, 2 rings 2 years etc. Historical records show that generally female Atlantic herring reached maturation at around 4-5 years. However, due to fishing pressure etc. the females are tending to reach maturation at 2-3 years.

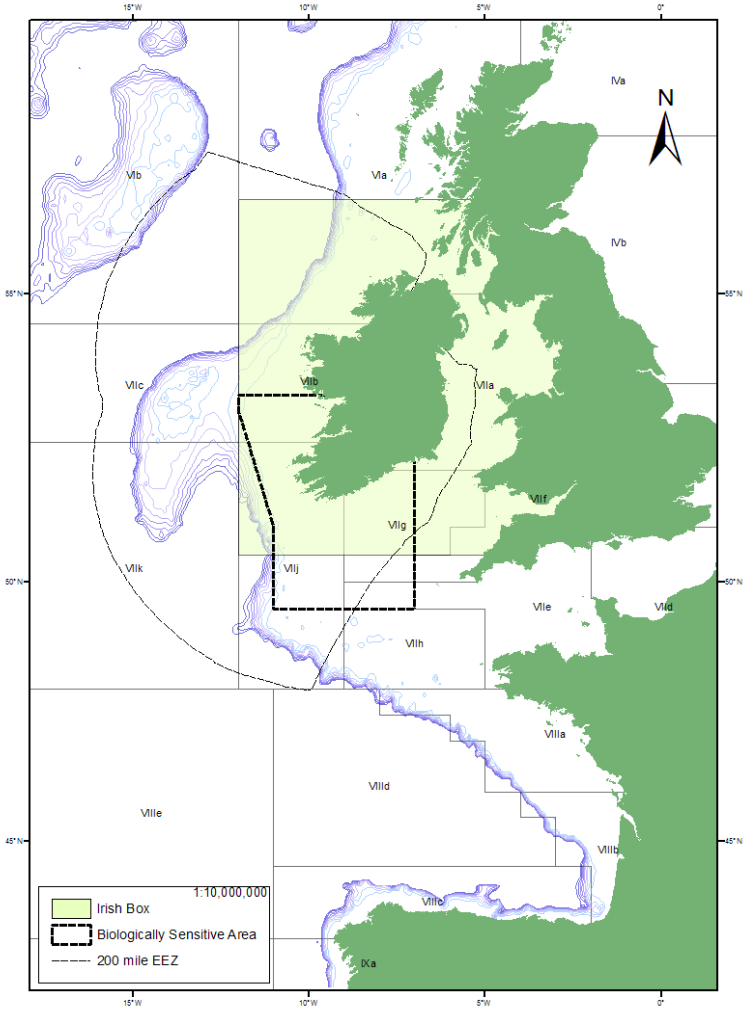
2012 having entered the stock. Recruitment has been lower in recent years, with an increase in 2016 with respect to 2015."

ICES HAWG (Herring Assessment Working Group) goes on to say:

"*At present there are no independent recruitment estimates... However, the acoustic survey age range has now been extended to include 1 ringers... This offers an independent estimate of recruits, and suggests a large increase in recruitment in recent years.*"

"*The state of the stock is not fully apparent from the results of the update assessment. Clearly, the stock has declined substantially from a high in 2012, as older cohorts disappeared and were not replaced - as recruitment has been below average since 2013. However the sudden change in fish behaviour as observed by the survey from 2014, with very differing availability of fish to the acoustic transducer, has meant that the assessment, following the Annex, cannot adequately track recent stock development* [fish recorded as swimming very close to the sea bottom]."

Figure 2-2 ICES Division VIIa South of 52° 30' N and VIIg,h,j,k (Celtic Sea and South of Ireland) and the Biologically Sensitive Area



Source: ICES (2009)

Finally, ICES HAWG (ICES, 2017) advises:

"Herring are an important prey species in the ecosystem and also one of the dominant planktivorous fish. The spawning grounds for herring in the Celtic Sea are well known and are located close to the coast. These spawning grounds may contain one or more spawning beds on which herring deposit their eggs. Individual spawning beds within the spawning grounds have been mapped and consist of either gravel or flat stone... Spawning grounds tend to be vulnerable to anthropogenic influences such as dredging, sand and gravel extraction, dumping of dredge spoil and waste from fish cages. There have been several proposals for extraction of gravel and to dump dredge spoil in recent years. Many of these proposals relate to known herring spawning grounds. ICES have consistently advised that activities that perturb herring spawning grounds should be avoided."

The Marine Institute, Fisheries Ecosystems Advisory Services (Ireland), cites that the smallest known spawning beds were found predominantly in the Celtic Sea, where nine beds were not larger than 0.1 km^2. The largest bed in the Celtic Sea was recorded as 36 km^2. In contrast spawning grounds recorded in the north and northwest of Irish waters, were considerably larger, with the largest being nearly 170 km^2, off north Donegal (O'Sullivan *et al.* 2013). However, for the larger spawning sites it is unclear whether they are contiguous beds, which seems unlikely given the specific spawning habitat requirements of Atlantic herring.

O'Sullivan et al. (2013) go on to say:

"[The 2012] *study is the first to show the locations of all herring spawning grounds in coastal waters of the Republic of Ireland. The results are based on extensive knowledge held within the fishing industry and validated with seabed data available from the national seabed survey programme. Larval modelling provides a first estimate of the spatial extent of larval dispersal fields from spawning beds which correspond with observed larval distributions from previous surveys. These results can be used for the purposes of marine spatial planning and to avoid negative impacts on herring spawning grounds. It is not possible to ascertain the contribution of individual spawning beds to recruitment of herring stocks. But to follow the precautionary approach it is necessary that all known beds are afforded maximum protection. The importance of herring as a forage fish…, and as a commercial resource…relies on favourable recruitment and the loss of spawning beds should to be avoided.*"

Figure 2-3 shows the distribution of known Atlantic herring spawning beds and grounds in Irish waters from the research conducted by O'Sullivan *et al.* (2013). It is apparent the known spawning habitat resources are distributed along the southern and western coastlines of the Republic of Ireland and off the northwestern coast of Northern Ireland.

Figure 2-3 Atlantic herring spawning beds

Source: O'Sullivan *et al.* (2013)

Table 2-1 presents the area of seabed associated with each of the 'heat' categories mapped with the available data. The area of 'high' confidence (9-12) 'heat' is used to set the greatest potential preferred spawning habitat available in the Welsh region. This value equates to 941.57 km^2 of 'high' 'heat' (2.66% of the total area of data used to delineate the potential Atlantic herring spawning area).

Table 2-1 The herring spawning population seabed area values

'Heat' (confidence) score	Category	Area (km^2)	Percentage of the Total Area of 'Heat' (%)
1 - 4	Low	16,410.73	46.36
5 - 8	Medium	9,997.94	28.25
9 - 12	High	941.57	2.66
All		35,396.07	77.27

The herring distribution and 'heat' map is presented in Figure 2-4. This sets the context of the herring spawning range within the Celtic Sea and the associated 'low', 'medium', 'high' and 'very high' confidence data for that population (along the Greenlink cable route).

In relation to this area of potential spawning habitat it is sensible to understand the status of the herring spawning populations, related fecundity and the 'space' required to maintain and support the total mass of spawning in any single year.

Atlantic herring spawning beds have quite specific characteristics. Due to data limitations and constraints the assessment has looked at data at a macro-scale. These data do not allow the necessary resolution to identify specific discrete and individual areas of seabed with the potential to act as Atlantic herring spawning beds. This is mainly because Atlantic herring spawning beds are typically small localised features[2].

2.1.2 Spawning Stock Biomass

Based on sources providing information on egg density at Atlantic herring spawning beds, number of eggs per female herring and the spawning stock biomass (SSB), it is possible to estimate a possible range for the total area of suitable spawning habitat for the Celtic Sea and South of Ireland Atlantic herring population (MarineSpace *et al*. 2013a). This can be compared to the values predicted in the mapping presented in this report and can contribute to the analysis of the effects on Atlantic herring in the wider context of the entire UK population. It should be noted that this is not a scientific attempt to quantify total Atlantic herring spawning habitat, but rather to allow order of magnitude comparisons of values predicted in two separate ways.

Given that SSB is likely to fluctuate over the 3 year period that the revised 2018 baseline will inform management decisions, the SSB value used in the revised assessment has been calculated as an average of the last 3 years of SSB data to help determine the total area of preferred habitat (ICES 2017).

The SSB values for the period 2014-2016 (inclusive) are presented in Table 2-2.

Table 2-2 Celtic Sea and South of Ireland Spawning Stock Biomass for the period 2014-2016

Year	SSB (tonnes)
2014	103,650
2015	69,979
2016	46,048
Mean Average	**73,226**

Source: ICES (2017)

[2] For example, a study undertaken by NOAA records size ranges of Atlantic spawning beds between 0.067 km^2 and 1.39 km^2 (Reid *et al.*, 1999)

The mean average Celtic Sea and South of Ireland SSB for the period 2014-2016 is calculated as 73,226 tonnes or 73,226,000 kg (Table 2-2). Taking the average weight of an adult Atlantic Herring as 0.225 kg this would equate to a spawning population of approximately 325,448,889 fish[3]. According to Stratoudakis *et al.* (1998), on prime Atlantic herring spawning beds, egg densities were measured at 750,000-2,500,000 eggs per m^2. An adult female herring carries between 20-50,000 eggs[4]. A 28 cm female from the Downs stock produces around 42,000 eggs per year[5]. These values equate to anything between 15-125 female herring per m^2, or 30-250 adult fish per m^2 in total (assuming one male per spawning female). Taking a mean number of eggs per m^2, and a mean number of eggs per female, yields a mean number of 46 females per m^2, and a total of 92 fish per m^2. At these spawning densities, 325,448,889 fish would require a total area of preferred habitat in the range of 1.3-10.8 km^2.

By comparing these estimated values with the measured values of 'heat' it is possible to assess the scale of available habitat in the context of preferred habitat as detailed above (see Table 2-1). The area surrounding the Greenlink cable route has 941.57 km^2 'high' 'heat' seabed. Therefore, assuming initially that 'high' 'heat' equates to preferred habitat it is evident that the available (preferred) habitat exceeds the highest value of 10.8 km^2. This calculation can be considered precautionary as it does not consider available 'marginal' habitat associated with 'medium' and 'low' 'heat', which increases the available potential habitat further.

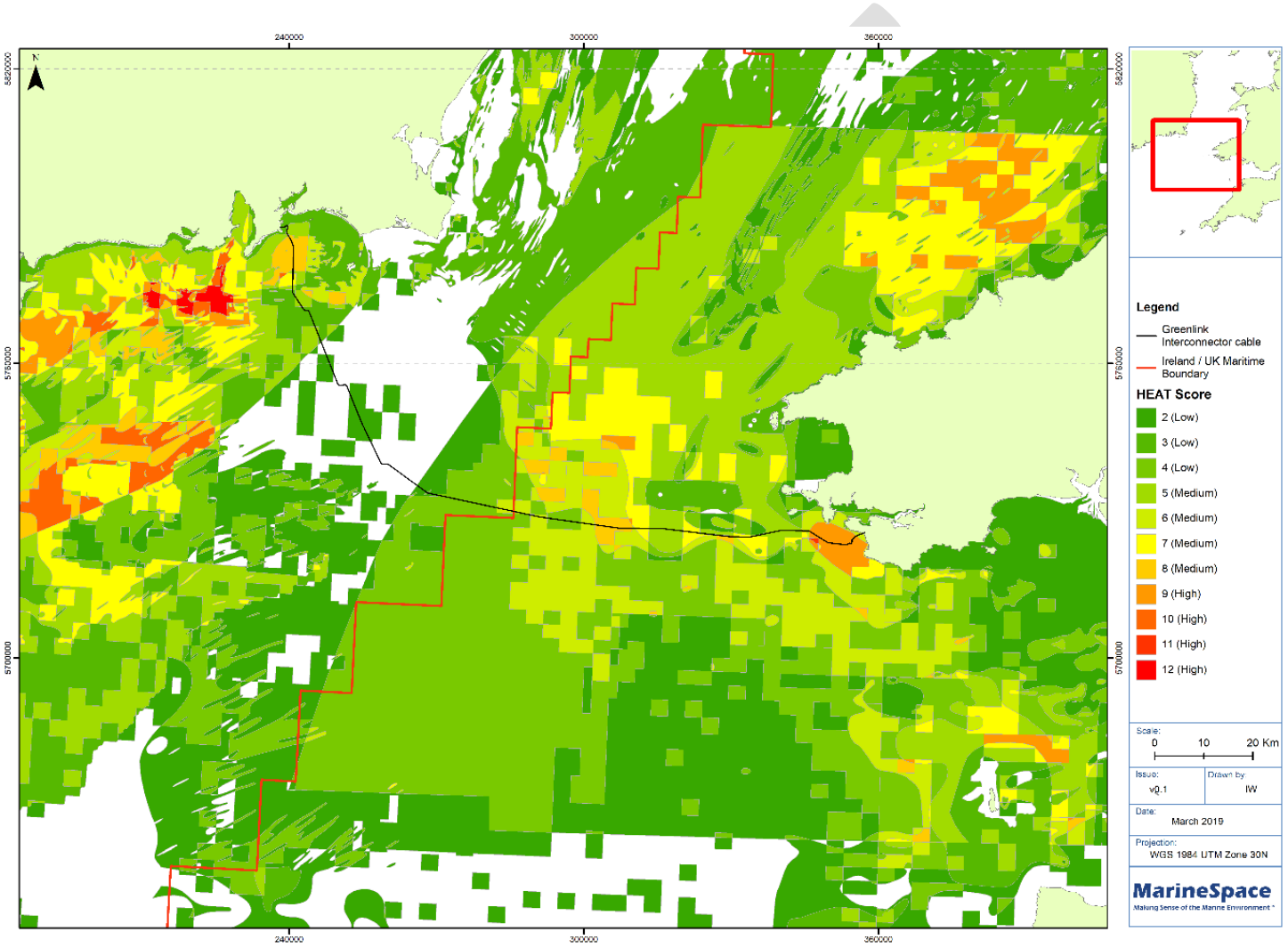
In the context of the population-scale 'heat' map (Figure 2-4) the percentage interaction between the Greenlink cable route and population-scale available preferred habitat in 'high' 'heat' locations = 0.02% (7.75 km^2 ÷ 35,396.07 km^2 x 100). See Section 2.5 for further detail.

[3] http:// www.clupea.net/stocks/NEAtlStocks/NorthSeaHer/NSAS_weca.htm

[4] http://www.gma.org/herring/biology/life_cycle/default.asp

[5] http://www.gov.scot/Publications/2015/05/4861/8

Figure 2-4 Distribution of data and 'heat' score associated with the Greenlink cable route and Atlantic herring potential spawning habitat



2.2 Sandeel Population-scale Mapping Results

MarineSpace *et al*. (2013b) identifies that sandeel habitat has quite specific characteristics which are still not well understood. The revised baseline has used data at a macro-scale. The necessary resolution to identify specific discrete and individual areas of seabed with the potential to act as sandeel habitat does not exist within the data. This is mainly because sandeel habitat is typically associated with localised features. Actual habitat, or habitat that could be used by sandeel in the future, will likely comprise discrete spatial extents, although these may be spread across wide areas of suitable seabed sediment habitat at a regional-scale.

The sandeel habitat mapping exercise relates to habitat used all year round, for all life stages of sandeel species.

It is thought that sandeel display an important level of site fidelity (sandeel are largely sedentary after settlement and form a complex of local (sub-) populations) making them potentially vulnerable at a sub-population level to direct habitat loss (removal) (MarineSpace *et al*. 2013b).

For the area of assessment, no ICES sandeel sub-population data interact with the Irish Sea region. The seabed area coverage considered for the Irish Sea population-scale sandeel habitat assessment is presented in Figure 2-5.

Figure 2-5 Distribution of data and 'heat' score associated with the Greenlink cable route and sandeel species potential habitat

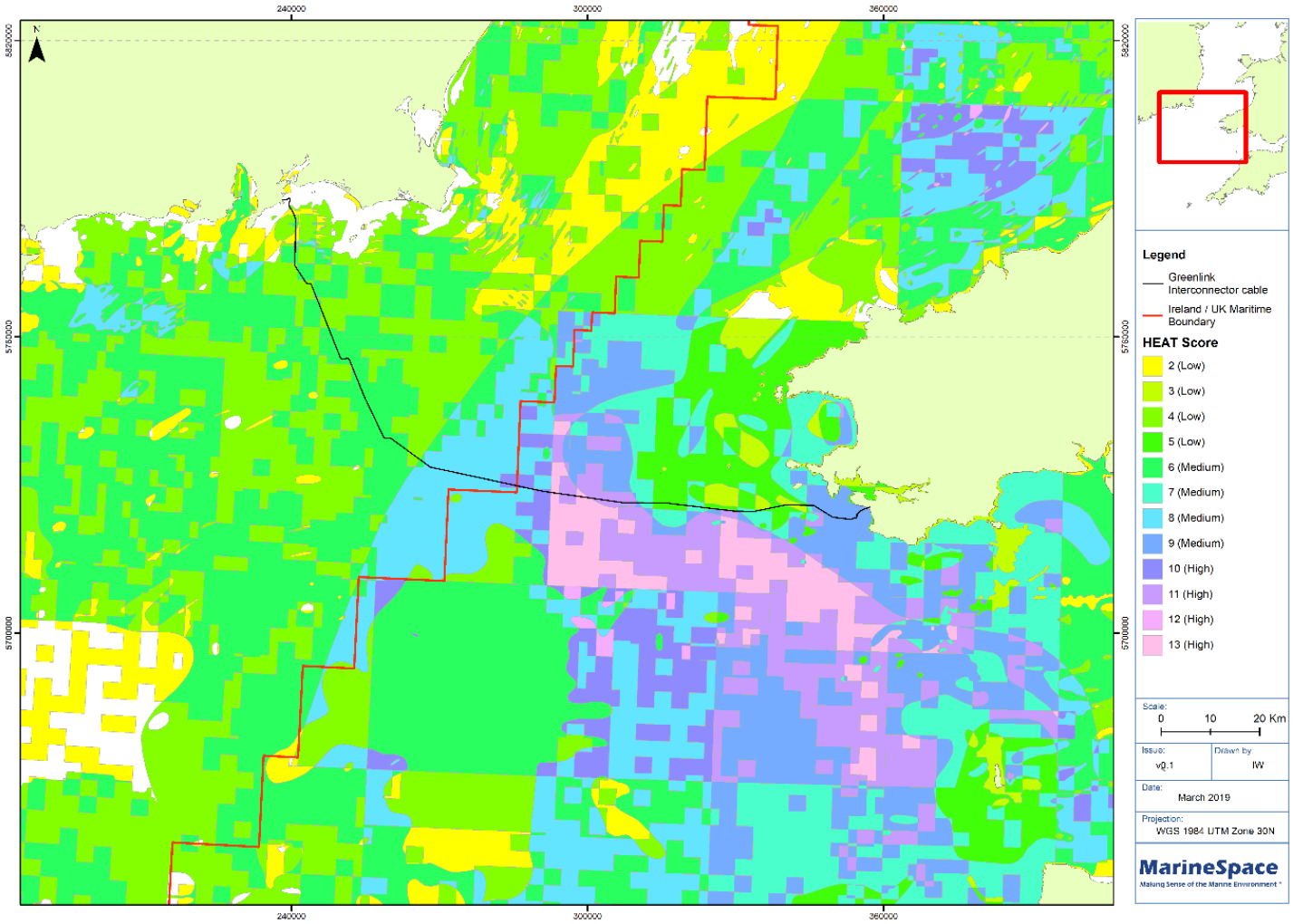


Table 2-3 Sandeel seabed habitat area values in the Greenlink cable route assessment area

'Heat' (confidence) score	Category	Area (km^2)	Total Area of Data (%)
2 - 5	Low	13,190.59	37.27
6 - 9	Medium	15,389.14	43.48
10 - 13	High	3,255.14	9.20
All		35,396.07	89.94

Table 2-3 presents the area of seabed associated with each of the 'heat' categories mapped with the available data. The area of 'high' confidence (10-13) 'heat' is used to set the greatest potential preferred habitat available to the sandeel population. This value equates to 3,255.14 km^2 of 'high' 'heat' (9.2% of the total area of data analysed). These values can be considered precautionary as they do not consider available 'marginal' habitat associated with 'medium' and 'low' 'heat'.

Figure 2-5 presents the 'heat' map in relation to the extent of data acquired and the study area.

In the context of the 'heat' map presented in Figure 2-5, the percentage interaction between Greenlink cable route and population-scale available preferred habitat in 'high' 'heat' locations = 0.04% (14.53 km^2 ÷ 35,396.07 km^2 x 100). See Section 2.6 for further detail.

2.3 Mapping Results

For both the Welsh and Irish region, a 'heat' map has been produced. The map is a magnified view of the population-scale figure. These investigations are presented to set context at the regional-scale, however; determinations of interactions between the Greenlink Interconnector route and preferred habitat are made at the wider population-scale. This is considered the most meaningful measure of interaction because Atlantic herring and sandeel species and available preferred habitat space are not limited by, or to, the Welsh/Irish waters boundary.

These points mean that a population-scale evaluation is the most meaningful in the context of management of marine aggregate dredging; in relation to possible effects on Atlantic herring potential spawning habitat and sandeel habitat.

2.3.1 Atlantic Herring

Overlays of the Greenlink cable route assessed for the Welsh and Irish region on the confidence 'heat' map for Atlantic Herring potential spawning habitat are presented in Figure 2-6 and Figure 2-7 respectively. Regions of 'high' 'heat' (i.e. confidence score 9-12 inclusive) are those areas of seabed where Coull et al. (1998) data layers have shown presence of Atlantic herring spawning populations. Areas of 'high' 'heat' are associated with the inshore region in Welsh and Irish waters. The

area that the cable interacts with in both Welsh and Irish waters is mostly ‘low’ and ‘medium’ ‘heat’ and in much of the Irish waters is associated with no ‘heat’ i.e. the majority of the Greenlink cable route are not associated with ‘preferred’ spawning habitat for Atlantic herring.

Figure 2-6 2018 'heat' map for Atlantic herring potential spawning habitat associated with Welsh waters

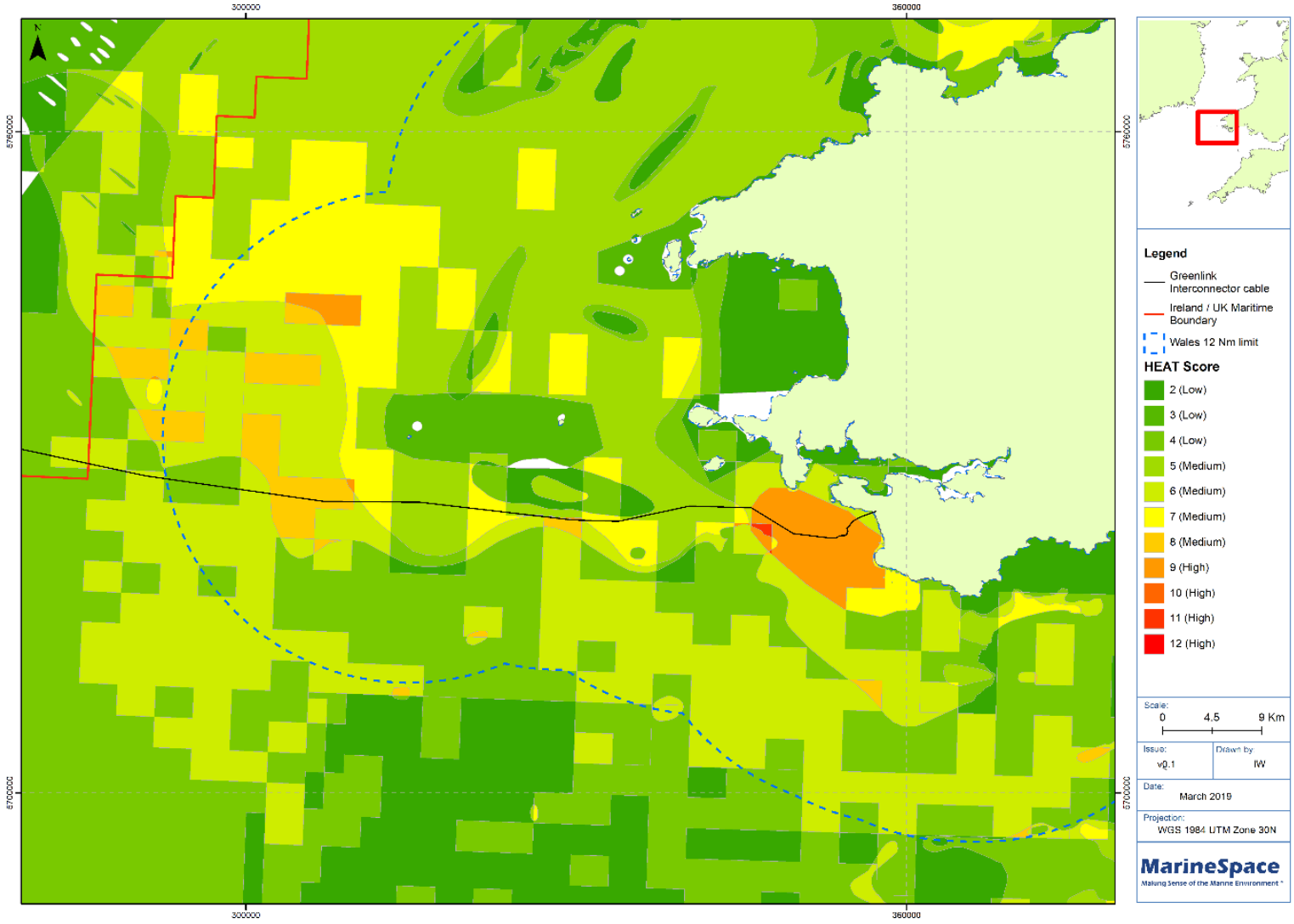
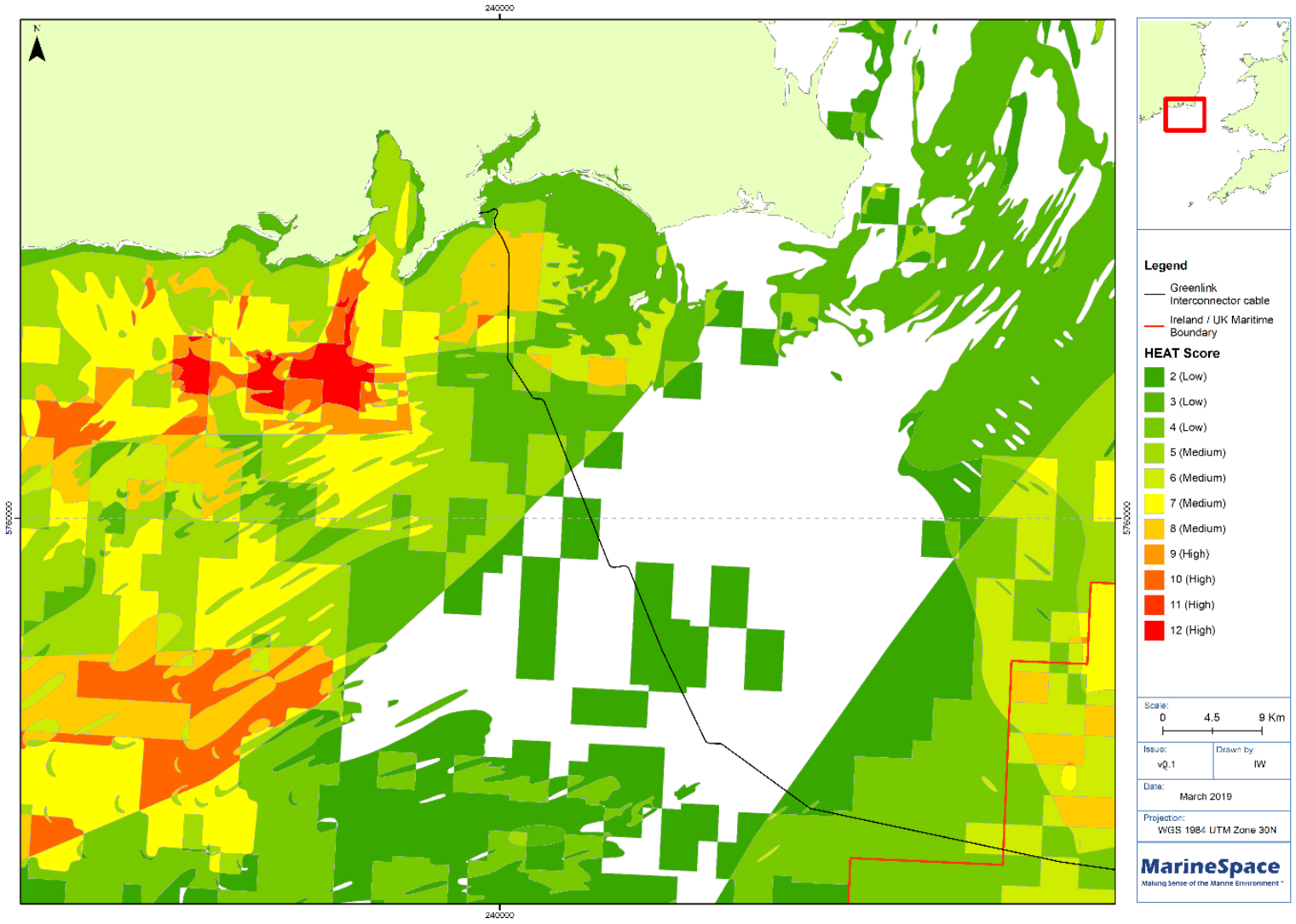


Figure 2-7 2018 'heat' map for Atlantic herring potential spawning habitat associated with Irish waters



2.3.2 Sandeel Species

Figure 2-8 and Figure 2-9 overlays the Greenlink cable route on the confidence 'heat' map for sandeel potential habitat in Welsh and Irish waters respectively.

Figure 2-8 illustrates the patchy distribution of 'heat' associated with sandeel habitat within Welsh waters with areas of 'high' heat in the west and areas of 'low' and 'medium' 'heat' further inshore. Areas of 'high' heat are associated with the BGS data layer showing areas of slightly gravelly sand.

Figure 2-9 shows that the Greenlink cable route in Irish waters interacts with only areas of 'low' and 'medium' 'heat'.

Figure 2-8 2018 'heat' map for sandeel species potential habitat associated with Welsh waters

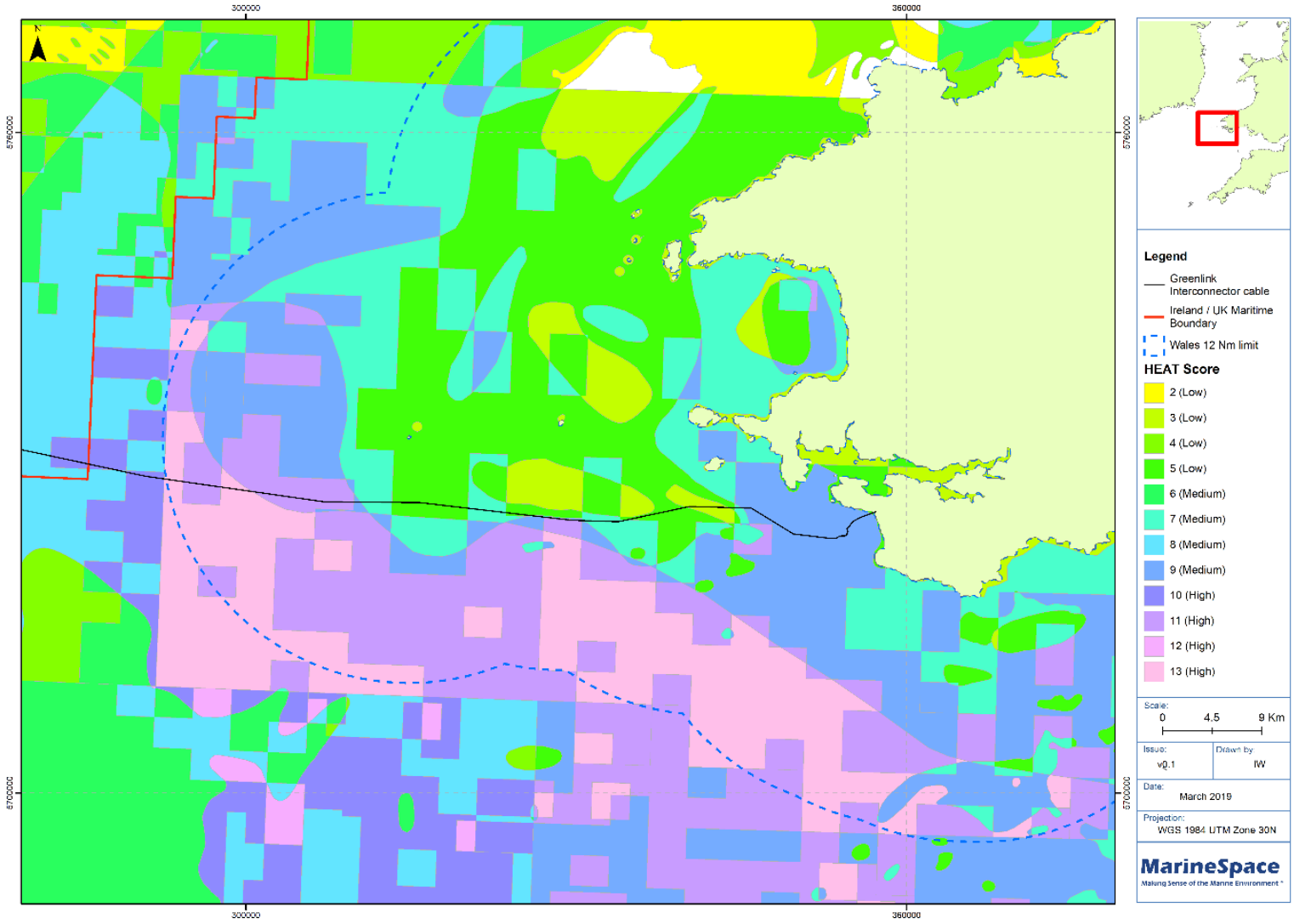
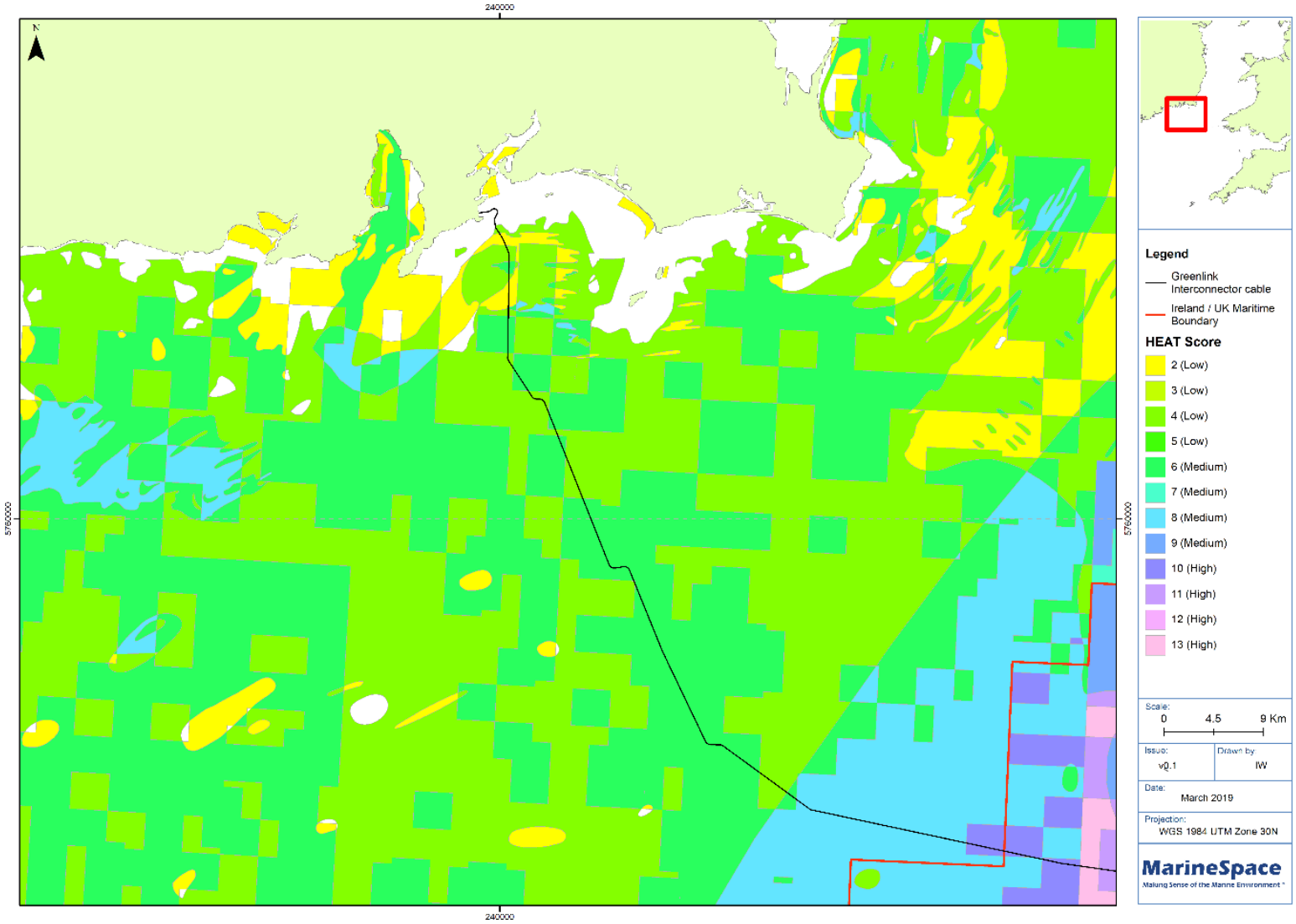


Figure 2-9 2018 'heat' map for sandeel species potential habitat associated with Irish waters



2.4 Atlantic Herring Results – Extent of Greenlink Cable Route Interaction with Potential Spawning Habitat

The area of interaction between the Greenlink cable route corridor and the various mapping 'heat' categories has been calculated for Welsh and Irish waters. The Greenlink cable route overlaps with a total area of 'heat' of 70.9 km^2 across its entire installation corridor[6]. This breaks down as:

- 25.81 km^2 of low 'heat' class;
- 37.34 km^2 of 'medium' 'heat' class; and
- 7.75 km^2 of 'high' 'heat' class.

At the Irish Sea spawning population-scale there is approximately:

- 16,410.73 km^2 of 'low' 'heat' class;
- 9,997.94 km^2 of 'medium' 'heat' class; and
- 941.57 km^2 of 'high' 'heat' class.

Therefore, the following values relate to the potential effect footprint associated with the Greenlink cable route with the Irish Sea spawning population habitat space:

- 0.16% of the total available 'low' 'heat' class;
- 0.37% of the total available 'medium' 'heat' class; and
- 0.82% of the total available 'high' 'heat' class.

2.5 Sandeel Species Results – Extent of Application Area Interaction with Potential Habitat: Regional-scale

The area of interaction between the Greenlink cable route corridor and the various mapping 'heat' categories has been calculated for Welsh and Irish waters. The Greenlink cable route overlaps with a total area of 'heat' of 80.26 km^2 across its entire installation corridor[6]. This breaks down as:

- 20.17 km^2 of low 'heat' class;
- 45.56 km^2 of 'medium' 'heat' class; and
- 14.53 km^2 of 'high' 'heat' class.

At the Irish Sea population-scale there is approximately:

- 13,190.59 km^2 of 'low' 'heat' class;
- 15,389.14 km^2 of 'medium' 'heat' class; and

[6] The installation corridor is approximately 500m wide along the entire route and is equivalent to the area surveyed by the marine cable route survey in 2018.

- 3,255.14 km^2 of 'high' 'heat' class.

Therefore, the following values relate the potential effect footprint associated with the Greenlink cable route with the Irish Sea spawning population habitat space:

- 0.15% of the total available 'low' 'heat' class;
- 0.30% of the total available 'medium' 'heat' class; and
- 0.45% of the total available 'high' 'heat' class.

2.6 *Project-specific Particle Size Analysis Data*

PSA data were collected along the Greenlink cable route by MMT (2019). These project-specific data have been compared to the BGS 1:250K seabed surface data to determine whether the two datasets provide an analogous or poor correlation or a separation in description of seabed sediment character (**Error! Reference source not found.**).

A number of sites identified within the MMT dataset show slight discrepancies in the correlation between the two classifications. This is particularly the case within Irish waters associated with the large extent of Sand. Here the MMT data indicate a slightly more coarser sediment classification showing gravelly Sand at many of the sample stations.

Gravelly Sand sits within the 'marginal' spawning habitat class for Atlantic herring. This means that the BGS data may slightly under-represent this marginal habitat across the large expanse of Sand in Irish waters. However, the variation is still only within one sediment particle size class and any increases from mapping this 'marginal' spawning habitat will still relate to a 'low' 'heat' class being mapped for Atlantic herring.

Gravelly Sand contributes to 'preferred' habitat for sandeel species and thus the representation of the MMT data do not alter the overall assessment or the 'heat' mapping for this receptor group.

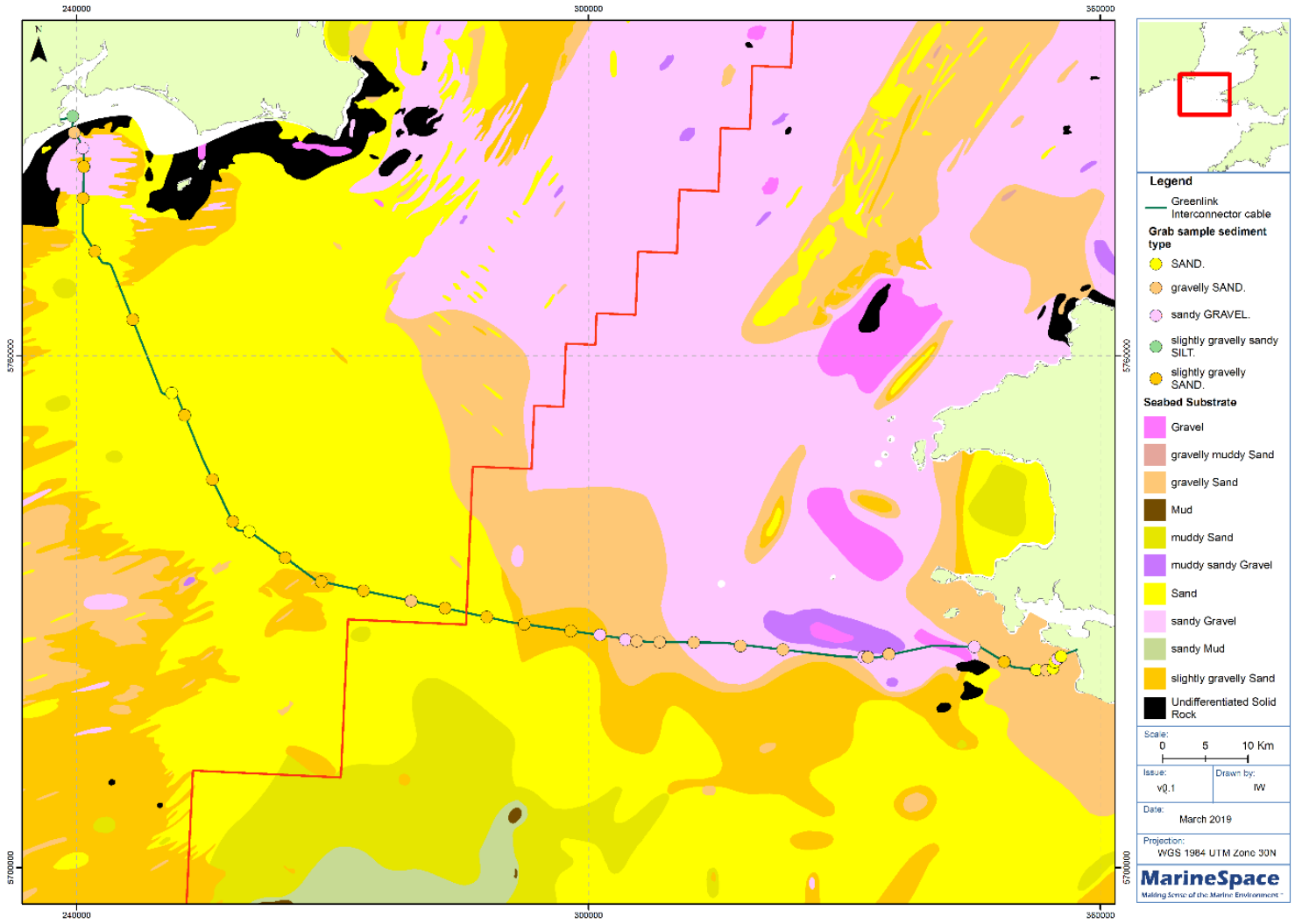
For Welsh waters the MMT data show a strong correlation with the BGS at many locations. However, there are some stations within the central Irish Sea extensive area of sandy Gravel (from the BGS data) that correlate with gravelly Sand (from the MMT data).

Sandy Gravel sits within the 'preferred' potential spawning habitat classification for Atlantic herring, whilst gravelly Sand represents 'marginal' potential spawning habitat. This means that the BGS data may slightly over-represent the availability of 'preferred' habitat within the assessment.

Sandy Gravel represents 'marginal' habitat for sandeel species and gravelly Sand 'preferred' habitat. Therefore, the MMT data indicate that there may be more habitat suitable for sandeel species within the cable corridor than represented within the BGS data.

However, when considering these observations, the discrepancies between the two datasets are expected given the likelihood of small-scale spatial variability in the principle components of the seabed sediment within the wider Irish sea area. Any small increases relating to 'preferred' sandeel species habitat within Welsh waters will still relate to a 'low' 'heat' class being mapped within the overall assessment.

Figure 2-10 BGS sediment data in the Irish Sea with PSA data for the Greenlink cable route



3. Atlantic Herring and Sandeel Species Conclusions – Extent of Interaction with Potential Spawning Habitat: Area-specific Scale

3.1 Welsh Waters

3.1.1 Atlantic Herring

The Greenlink cable route corridor interacts with 7.75 km^2 of 'high' 'heat' within Welsh waters. This area falls just offshore of Freshwater West and it corresponds with the Coull *et al*. (1998) data layer showing the presence of Atlantic herring spawning areas. However, when comparing the BGS data layer in this area with the project-specific PSA data many of the samples gathered in this area are shown to differ from the BGS data layer. There are a number of PSA data samples that are identified as Sand. This suggests that this area is less suitable for Atlantic herring spawning than is suggested by the 'high' 'heat' level shown in the 'heat' mapping. In addition, the percentage of 'high' 'heat' that the cable route intersects with is 0.02% of that available within Welsh waters.

3.1.2 Sandeel

The Greenlink cable route corridor interacts with 12.78 km^2 of 'high' 'heat' within Welsh waters. The area in which 'high' 'heat' is present falls to the west, close to the UK/Republic of Ireland median line and correlates with the BGS data layers showing the presence of sand and slightly gravelly sand. The installation of the Greenlink cables is unlikely to cause changes to seabed sediments within the area so long as burial depth is achieved. Therefore, no habitat will be lost in this area unless rock dumping is required along the length of the cable route. In addition, the percentage of 'high' 'heat' that the cable route intersects with is 0.39% of that available within Welsh waters.

3.2 Irish Waters

3.2.1 Atlantic herring

The Greenlink Interconnector cable does not interact with 'high' 'heat' within Irish waters. However, an area in the nearshore is defined as 'medium' 'heat' indicating potential or 'marginal' spawning habitat due to the nearshore variable nature of the seabed composition. Spawning bed analysis over the Proposed Development indicates that the cable route does interact with one coastal herring spawning site, referred to as the Dunmore East herring spawning grounds (O'Sullivan *et al*. 2013). Therefore, potential does occur for the cable route to interact with any Atlantic herring spawning habitat within Irish waters. The known locations of all other spawning beds and grounds for Atlantic herring in Irish waters correlate with the

south, western and northwestern parts of the inshore around the Republic of Ireland and Northern Ireland coastline, indicating a wide distribution of spawning grounds (Figure 2.3).

3.2.2 Sandeel

The Greenlink cable route interacts with 1.75 km^2 of 'high' 'heat' within Irish waters. The area in which 'high' 'heat' is present falls to the east, close to the Republic of Ireland /UK median line and correlates with the BGS data layers showing the presence of sand and slightly gravelly sand. The installation of the Greenlink cables is unlikely to cause changes to seabed sediments within the area so long as burial depth is achieved. Therefore, no habitat will be lost in this area.

REFERENCES

1 Coull K.A., Johnstone R., and Rogers S.I., (1998) Fisheries Sensitivity Maps in British Waters. Published and distributed by UKOOA Ltd.

2 Ellis J.R., Milligan S.P., Readdy L., Taylor N., and Brown M.J., (2012) Spawning and nursery grounds of selected fish species in UK waters. Sci. Ser. Tech. Rep., Cefas Lowestoft, 147, 56 pp.

3 Folk R.L. (1954) The distinction between grain size and mineral composition in sedimentary rock nomenclature. Journal of Geology, 62, 344-359.

4 ICES (2017) Herring Assessment Working Group for the Area South of 62 deg N (HAWG), 14-22 March 2017, ICES HQ, Copenhagen, Denmark. ICES CM 2017/ACOM:07. 856 pp.

5 ICES (2009) Report of the ICES Advisory Committee, 2009. ICES Advice, 2009. Books 1 - 11. 1,420 pp.

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

7 MarineSpace Ltd, ABPmer Ltd, ERM Ltd, Fugro EMU Ltd and Marine Ecological Surveys Ltd, (2013a) Environmental Effect Pathways between Marine Aggregate Application Areas and Atlantic Herring Potential Spawning Habitat: Regional Cumulative Impact Assessments. Version 1.0. A report for the British Marine Aggregates Producers Association.

8 MarineSpace Ltd, ABPmer Ltd, ERM Ltd, Fugro EMU Ltd and Marine Ecological Surveys Ltd, (2013b) Environmental Effect Pathways between Marine Aggregate Application Areas and Sandeel Habitat: Regional Cumulative Impact Assessments. Version 1.0. A report for the British Marine Aggregates Producers Association.

9 MMT (2019) Greenlink Environmental Survey Report. Revision 02. March 2019.

10 O'Sullivan D., O'Keeffe E., Berry A., Tully O., and Clarke M., (2013) An Inventory of Irish Herring Spawning Grounds. Irish Fisheries Bulletin No. 42, 2013. The Marine Institute, Fisheries Ecosystems Advisory Services, Rinville, Oranmore, Co. Galway. ISSN: 1649 5055.

11 Payne M.R., (2010) Mind the gaps: a state-space model for analysing the dynamics of North Sea herring spawning components. ICES Journal of Marine Science, 67, 1939–1947. [online] Available at: http://icesjms.oxfordjournals.org/cgi/doi. [Accessed November 2017].

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

13 Stratoudakis Y., Gallego A., and Morrison J.A., (1998) Spatial distribution of developmental egg ages within a herring Clupea harengus spawning ground. Marine Ecology Progress Series, 174, 27–32.