Norfolk Vanguard Offshore Wind Farm

Appendix 7.2
Envision Sabellaria Reef Mapping

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Approved by: Ruari Lean and Rebecca Sherwood

Signed: [redacted]

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Norfolk Vanguard & Norfolk Boreas Sabellaria Review

May / 2018

Review and interpretation of survey data

Site

Norfolk Vanguard and Norfolk Boreas Offshore Wind Farms

Prepared for

Royal HaskoningDHV & Vattenfall

Prepared by

Envision Mapping Ltd.

Author(s)

Ian Sotheran

PREPARED FOR	Royal HaskoningDHV & Vattenfall
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PREPARED BY

Envision Mapping Ltd
Mallan House
Bridge End
Hexham
Northumberland
NE46 4DQ
United Kingdom

T: +44 (0)1434 60 76 71
E: mail@envision.uk.com

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Envision Mapping's environmental policy involves the use of renewable electricity and recycled paper that is manufactured using wind-generated electricity

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1. Introduction

Norfolk Vanguard Limited and Norfolk Boreas Limited (affiliate companies of Vattenfall Wind Power Ltd (VWPL)) are seeking Development Consent Orders for Norfolk Vanguard and Norfolk Boreas, two offshore wind farms (OWF)s in the southern North Sea. The two wind farms have a shared offshore cable corridor within which export cables will be installed connecting the wind farms with the landfall area at Happisburgh South.

The offshore export cable corridor passes through the Haisborough, Hammond and Winterton (HHW) Special Area of Conservation (SAC) (Figure 1). The SAC contains a series of sandbanks which meet the Annex I habitat description for "Sandbanks slightly covered by sea water all the time". The biogenic reefs of the worm *Sabellaria. spinulosa* are also a protected feature of the SAC.

A site characterisation survey of the Norfolk Vanguard and Norfolk Boreas offshore cable corridor (Fugro, 2016) identified potential presence of the biotope '*Sabellaria spinulosa* on stable circalittoral mixed sediment' (SS.SBR.PoR.SspiMx).

SS.SBR.PoR.SspiMx is a component part of *S. spinulosa* reefs, however Annex I reefs are not always present where the biotope occurs. This report provides a review of all available data pertaining to the likelihood, presence, distribution, and nature of *S. spinulosa* biotopes and reefs within the Norfolk Boreas and Vanguard offshore cable corridor and Norfolk Vanguard West OWF area has been undertaken with the specific aims of;

i. Identifying the presence and extent of any *S. spinulosa* reef within the Norfolk Boreas and Vanguard offshore cable corridors which fall within the Haisborough, Hammond and Winterton SAC, and

ii. If found, to assess any areas in context with the protected features within the SAC.

A draft 'Norfolk Vanguard & Norfolk Boreas Sabellaria Review' was provided to Natural England in January 2018 for consultation. The datasets which have been reviewed and utilised within the present updated review are outlined below, and include information provided by Natural England on the 15th March 2018:

- Geophysical data (sidescan sonar and multibeam bathymetry) from the project survey undertaken by Fugro, 2016.
- Video and grab samples collected as part of the same Fugro 2016, survey campaign
- Benthic sample data from East Anglia Zone Environmental Appraisal (MESL, 2012).
- Regional and other datasets were sourced from the Regional Seabed Monitoring Plan (RSMP) baseline assessment dataset (Cooper & Barry, 2017).

- Sample records and habitat extents from the East Coast Regional Environmental Characterisation study (MALSF, 2011)

- Draft sample records and notes were reviewed from data from the CEFAS cruise (code CEND 11/16) (McIlwaine *et al*, 2017) but following advice from the Marine Management Organisation these data were not incorporated into habitat extent mapping.

- Frojan, 2013 Benthic Survey of Inner Dowsing, Race Bank and North Ridge cSAC and of Haisborough, Hammond and Winterton cSAC

- Gardline 2010 Bacton to Baird pipeline route and environmental survey.

In addition, Norfolk Vanguard Limited were recently advised By JNCC and Natural England of areas which the SNCBs intend to manage as Annex I *S. spinulosa* reefs (JNCC & NE, 2018). Some of the area to be managed as reef intersect with Norfolk Vanguard West and the cable corridor (Figure 1).

From reviewing the site specific geophysical and sample data (Fugro 2016) and augmenting this with other available data, the areas mapped as potential Sabellaria biotope have been refined to more precise and spatially constrained areas which are supported by sample data. These areas and samples have been further reviewed to identify where *S. spinulosa* reef may occur and the characteristics/ 'reefiness' of these areas have been assessed in accordance with Gubbay et al, (2007) and Foster-Smith & Hendrick (2006).

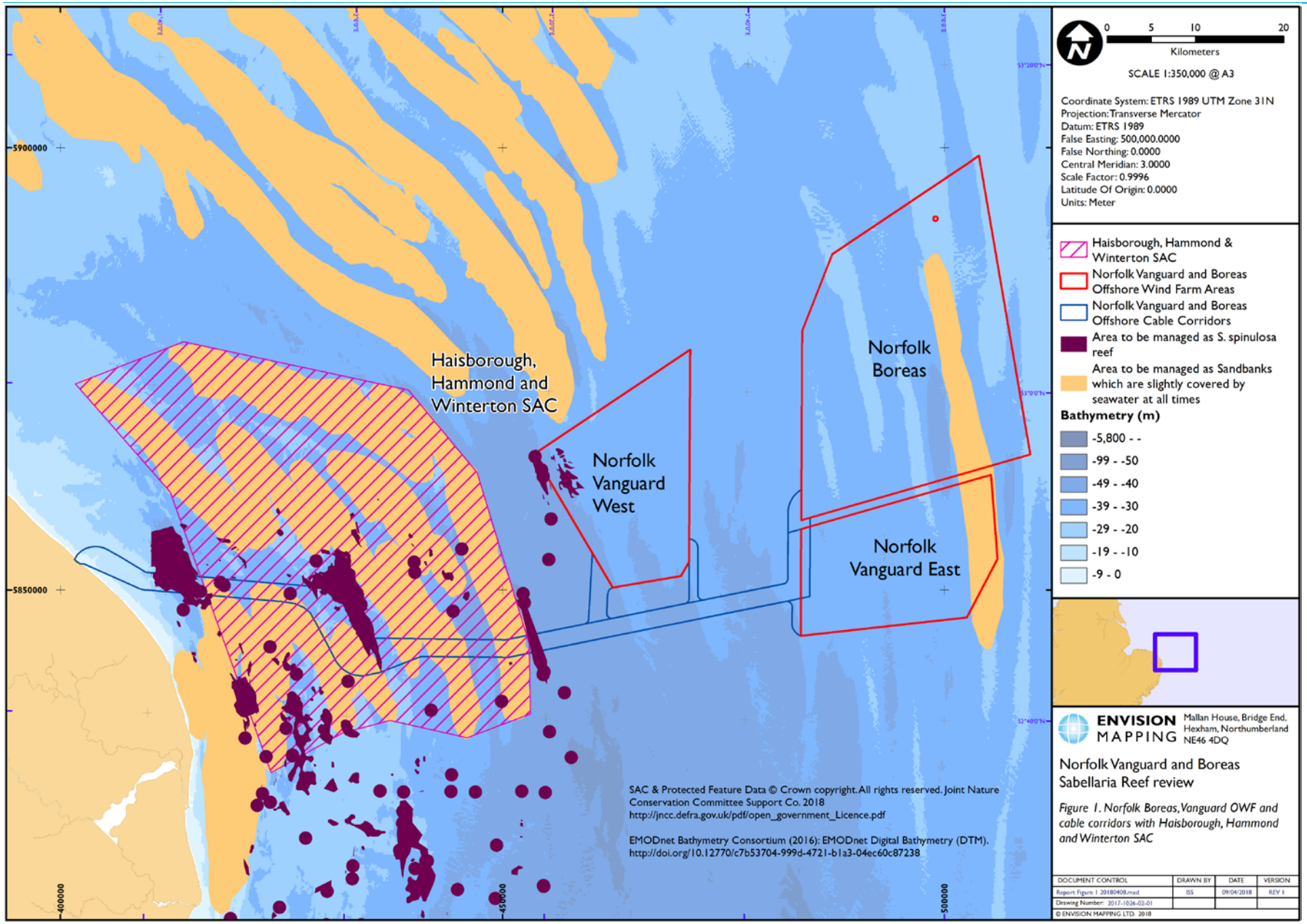

Figure 1. *Norfolk Boreas, Vanguard OWF, and cable corridors with Haisborough, Hammond and Winterton SAC shown*

2. Methods for analysis

The overarching strategy for the interpretation of the available data is to combine information from the geophysical data with the benthic sample data using image processing and spatial statistical analysis. This process uses the sample data to 'ground truth' the geophysical data, a strategy which is described in the Mapping European Seabed Habitats (MESH) documentation from which Figure 2 is taken (MESH, 2008). The existing geophysical data require processing and interpolation prior to integration so that the data are in a suitable format for the mathematical analyses. The main outputs are descriptions of habitats and distribution maps.

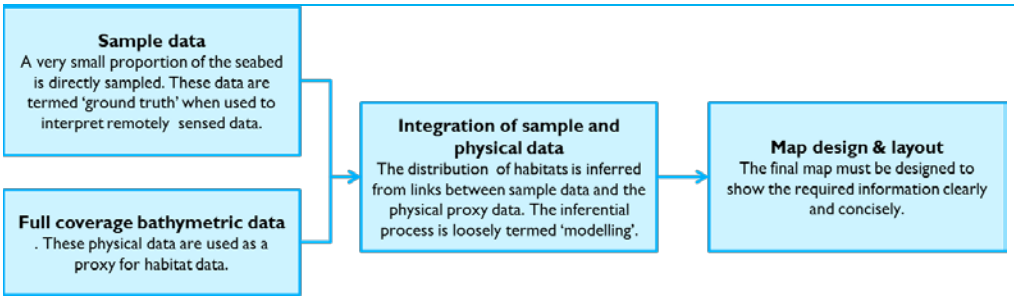

Figure 2.
A flow chart of the main stages in making a habitat map by integrating sample data and full coverage physical data

Several approaches have been used to map the cable corridor and OWF area, and the resultant maps from each combined to produce an ensemble map incorporating confidence.

2.1. Geophysical data

Site characterisation geophysical data collected in 2016 by Fugro (Fugro, 2016), for the Norfolk Vanguard and Norfolk Boreas cable corridor area and Norfolk Vanguard West site have been analysed within this report. Of the data available, the most suitable for habitat mapping and detection of *S. spinulosa* reefs are bathymetry and sidescan sonar supported by rugosity information which is a derivative of the bathymetric data (Figures 3 to 5).

Bathymetry was used as gridded data at a resolution of 1m. In addition to detailing the depth of the seafloor, bathymetry can be used to derive other parameters such as an index of rugosity which can highlight where the seabed is variable in nature. Bathymetry data were processed, and the final analysis used a 5m resolution to match other derivatives and datasets.

Seabed terrain heterogeneity can indicate the complexity of a habitat and is known to be correlated to distribution of benthic fauna (Tappin *et al.*, 2010), associated with areas of *S. spinulosa* reefs and has been used to detect reefs around the UK (McIlwaine, 2017 & MESL, 2012). Rugosity was calculated using a terrain ruggedness index which produces gridded data suitable for analysis. Other derivates from bathymetry such as slope of aspect were excluded from analysis as they are too closely correlated to rugosity.

The sidescan data were used as gridded mosaics for the cable and OWF areas.

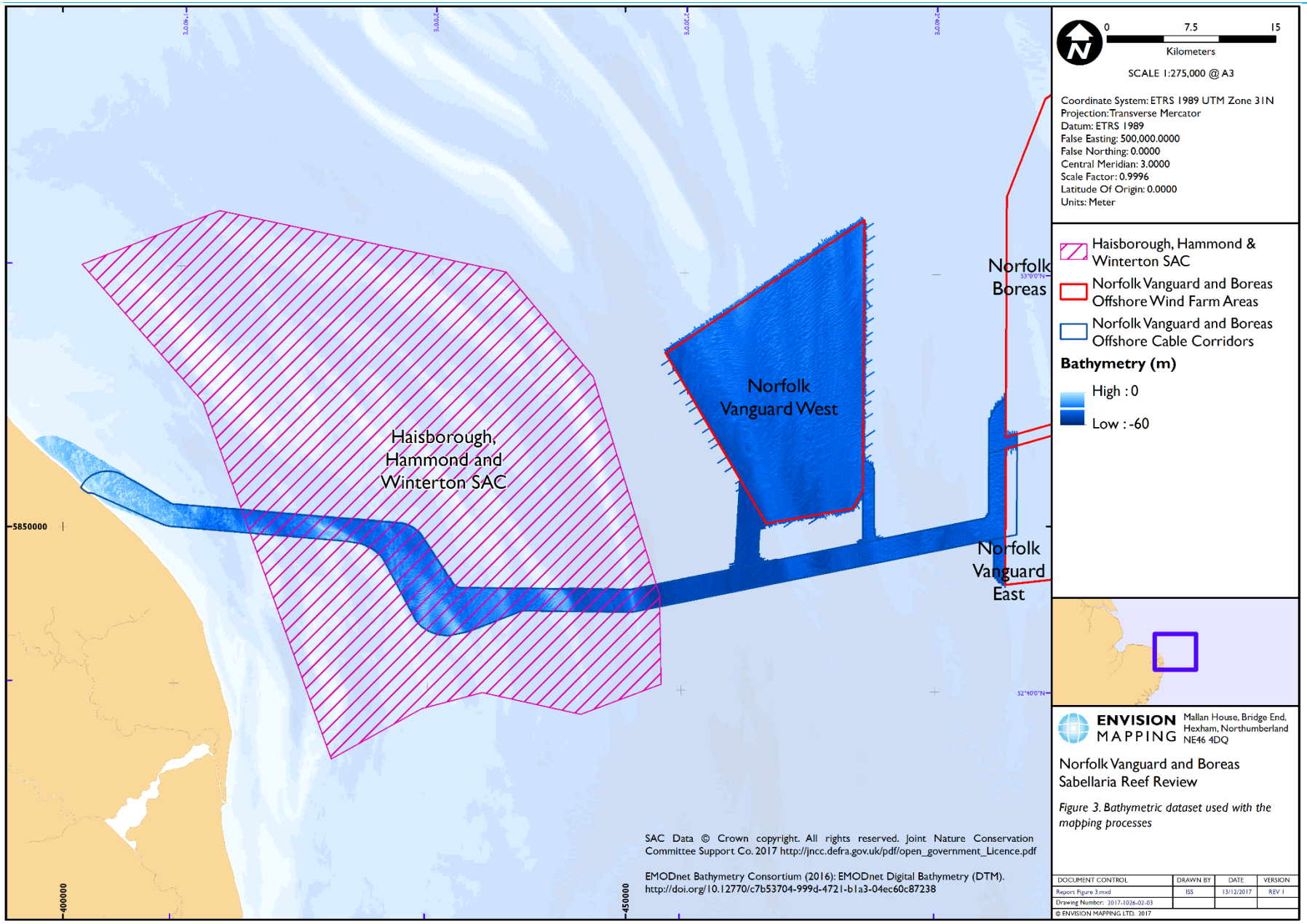

Figure 3. *Bathymetric dataset used with the mapping processes*

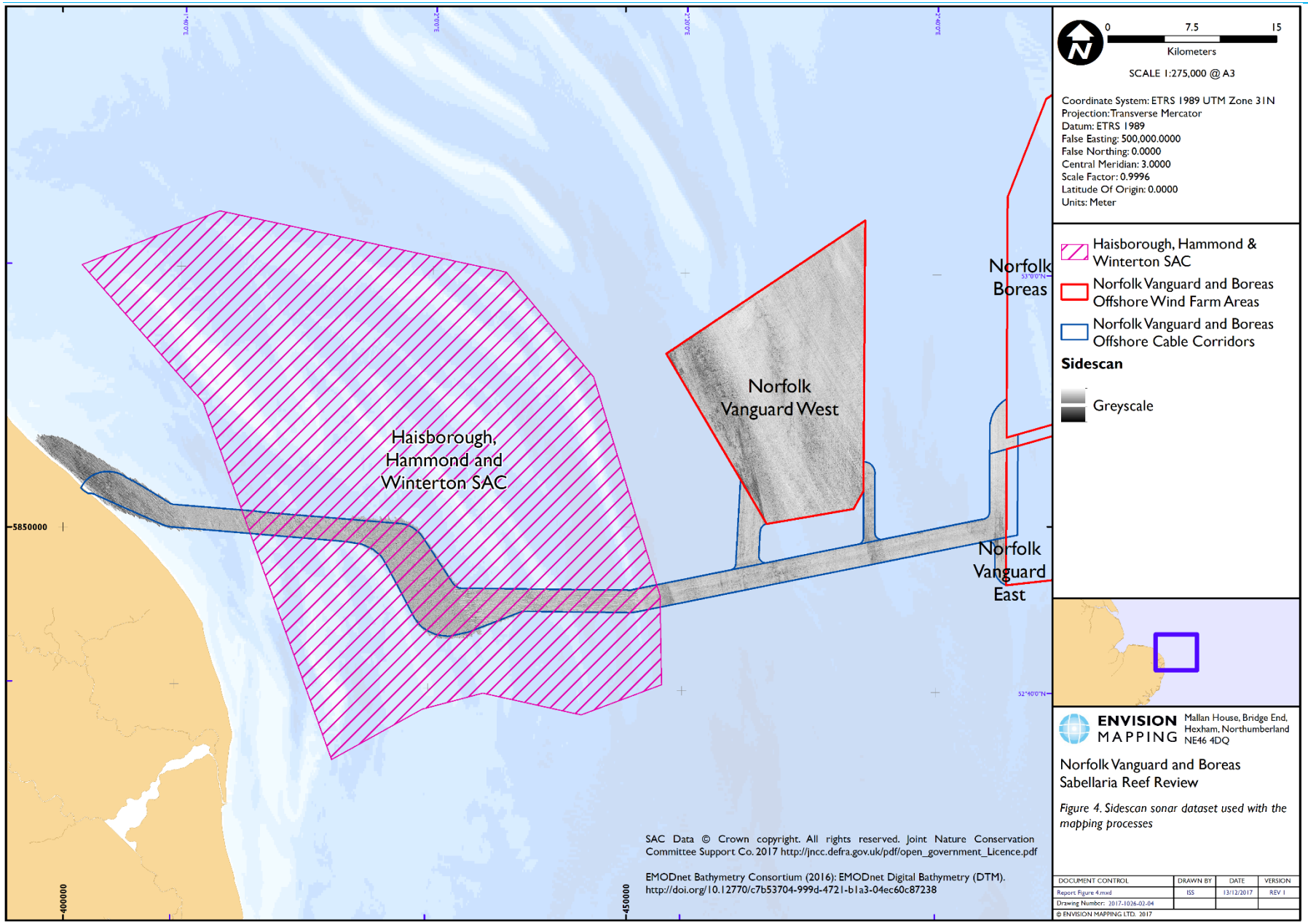

Figure 4. *Sidescan dataset used with the mapping processes*

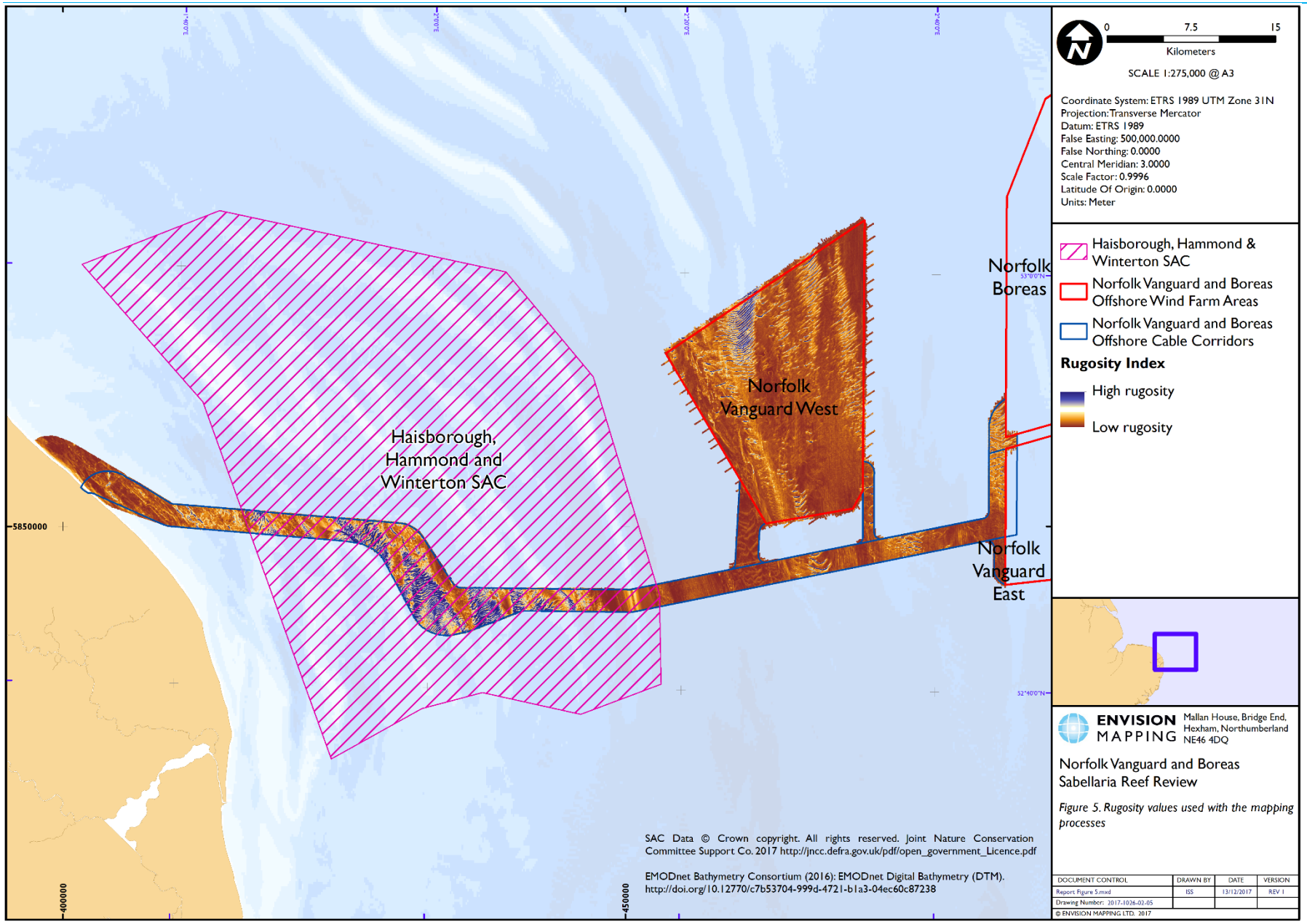

Figure 5.
Rugosity index data used with the mapping processes

2.2. Sample data

Sample data from stations within the Norfolk Vanguard and Norfolk Boreas cable corridor area and Norfolk Vanguard West OWF site included samples collected as part of the Norfolk Vanguard Benthic characterisation surveys (Fugro, 2016) and part of the East Anglia Zone Environmental Appraisal (MESL, 2012). Full particle size analysis (PSA) data, benthic infauna from grabs and images and descriptions from video footage were available for these samples.

Regional and other datasets were sourced from the Regional Seabed Monitoring Plan (RSMP) baseline assessment dataset[1] (Cooper & Barry, 2017). These data incorporate a range of surveys from a variety of sources with accompanying infaunal and PSA data. Of particular relevance is data collected by Cefas for the Inner Dowsing, Race Bank and North Ridge along with Haisborough, Hammond and Winterton survey data from 2013 for which updated reef assessment data is available.

The EC REC, (MALSF, 2011) collected ground truthing data to which a 'reefiness' assessment has been applied (Gubbay et al, 2007, Foster-Smith & Hendrick, 2006), these data have been used to determine the extent of reefs within the cable corridor and OWF areas.

Sample records and notes were reviewed from data from the CEFAS cruise (code CEND 11/16) (McIlwaine *et al*, 2017) and records where *S. spinulosa* reef was observed were noted but as these are currently preliminary or draft they were not used within the current models. Once these data are finalised it may be possible to incorporate them within the mapping process.

The majority of the grab samples had not been attributed to a UK or European Nature Information System (EUNIS) marine habitat category therefore the physical parameters (such as PSA) were used to attribute each sample with a EUNIS/Marine Nature Conservation Review (MNCR) category based upon the varying percentages of gravels, sands, and muds (after Long, 2006). Samples from the Norfolk Vanguard Benthic characterisation surveys (Fugro, 2016) had been attributed to a habitat/biotope category and these have been used to inform the study. Where habitat categories included a biological element, which is unlikely to be distinguished or detected from acoustic data then these samples were pooled to a high level within the classification (e.g. SS.SCS.CCS.MedLumVen and SS.SCS.CCS.Pkef were pooled to SS.SCS.CCS) for mapping purposes, but original category retained for sample mapping.

[1] https://www.cefas.co.uk/cefas-data-hub/dois/rsmp-baseline-dataset/ *[accessed October 2017]*

The marine habitat categories used within the mapping process are shown in Table 1 below:

Table 1.
Marine habitat categories used with the mapping processes

MNCR Habitat/Biotope	Name	Composite of biotopes
SS.SSa.CFiSa	Circalittoral fine sand	SS.SSa, SS.SSa.CMuSa, SS.SSa.CFiSa, SS.SSA.CFiSa.EpusOborApr
SS.SMx.CMx	Circalittoral mixed sediment	SS.SMx, SS.SMx.CMx
SS.SMu.CMuSa	Circalittoral sandy mud	SS.SMu, SS.SMu.CMuSa
SS.SCS.CCS	Circalittoral coarse sediment	SS.SCS, SS.SCS.CCS, SS.SCS.CCS.MedLumVen, SS.SCS.CCS.Pkef
SS.SBR.PoR.SspiMx	*Sabellaria spinulosa* on stable circalittoral mixed sediment	SS.SBR.PoR.SspiMx

Video data and grab sample data have been reviewed and assessed for the presence of *S. spinulosa* and were used to assess the likelihood of reef habitat occurring in the vicinity of each sample.

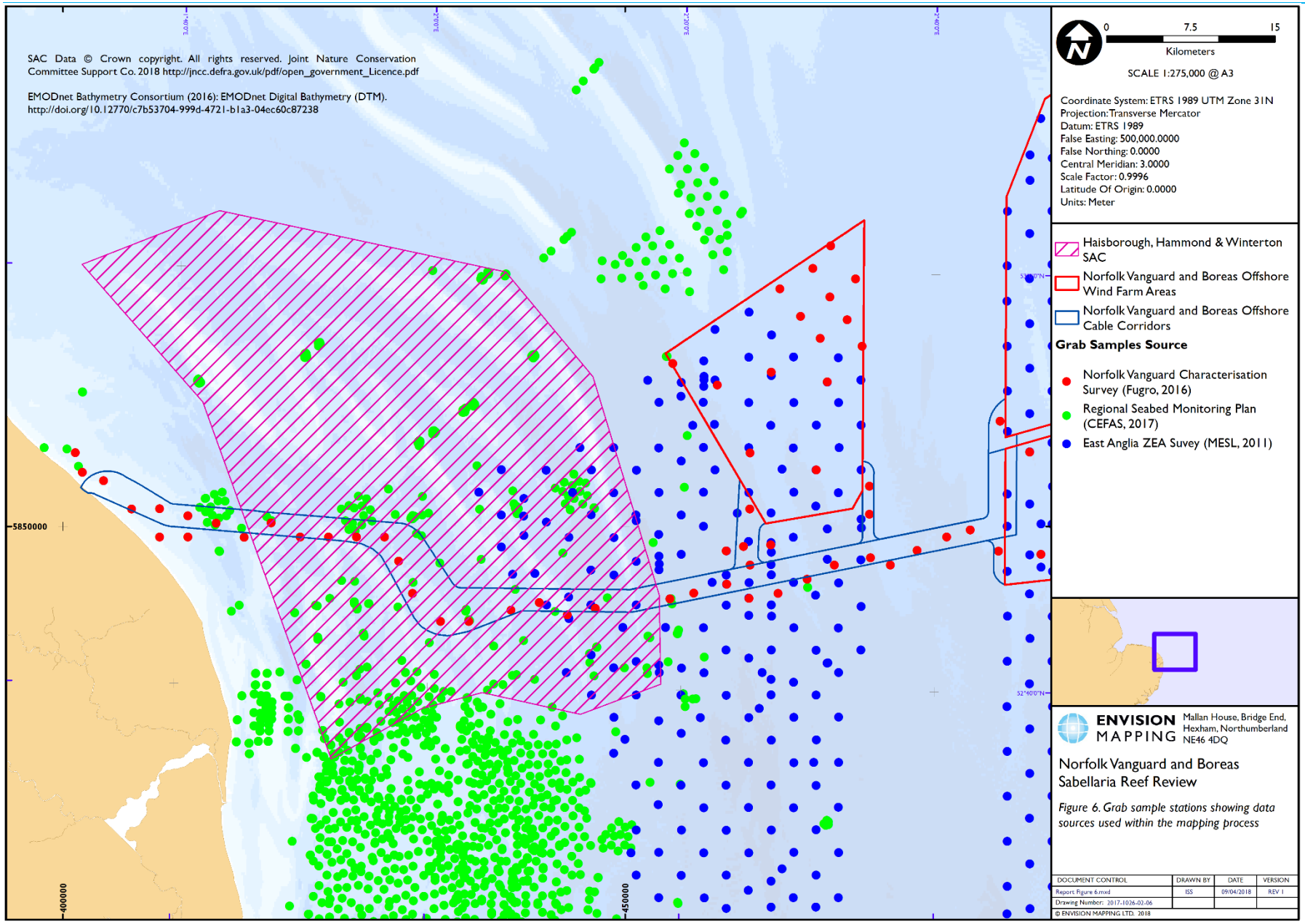

Figure 6.
Grab sample stations showing data sources used within the mapping process

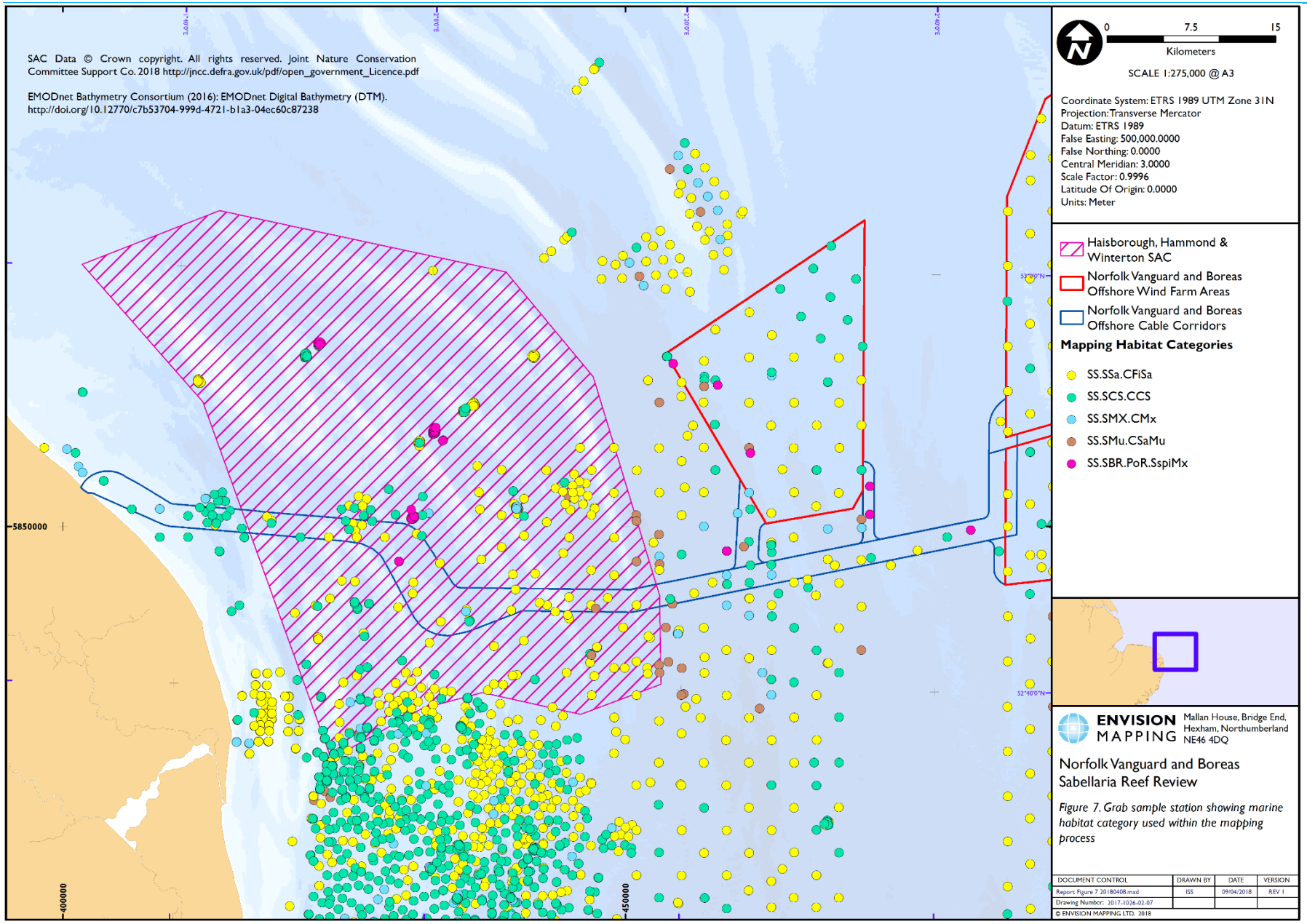

Figure 7.
Grab sample station showing marine habitat category used within the mapping process.

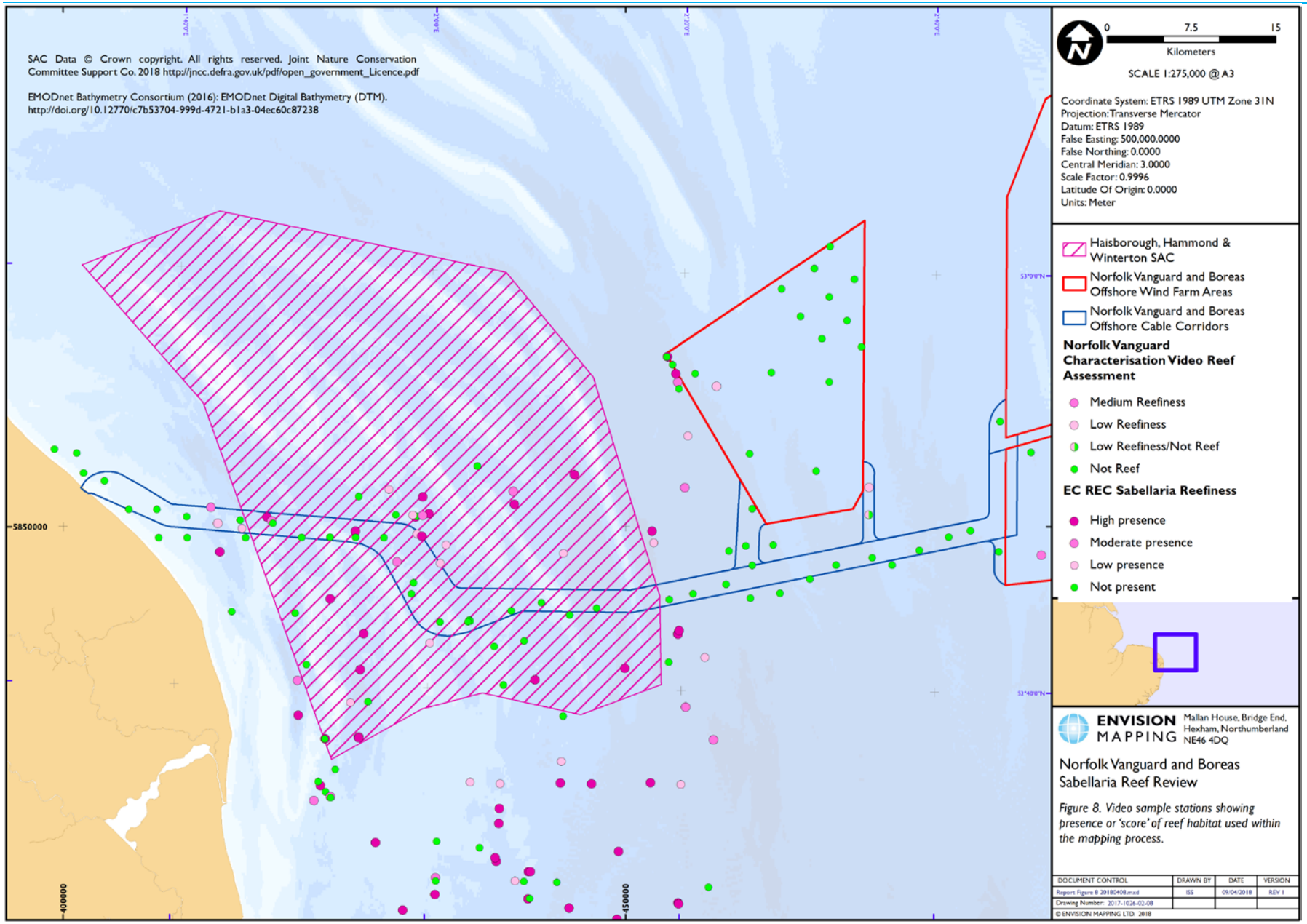

Figure 8.
Video sample stations showing presence or 'score' of reef habitat used within the mapping process.

2.3. *Sabellaria spinulosa* review

Sabellaria spinulosa is a ubiquitous species found in varying abundances throughout the North Sea present as solitary individuals, thin crusts, or reef systems; the biotope SS.SBR.PoR.SspiMx is commonly attributed to samples with elevated numbers of individuals. Therefore, in order to distinguish whether aggregations of this species should be considered as reef, the methodology for determining 'reefiness' (Gubbay 2007) has been used with this review. The main focus of the study was to assess the likelihood, presence, distribution, and nature of *S. spinulosa* reef existing within the Norfolk Vanguard and Norfolk Boreas cable corridor area and Norfolk Vanguard West OWF site. Therefore, an assessment was made of the currently mapped distribution of the biotope SS.SBR.PoR.SspiMx along with the samples which contributed to the mapping of these extents. Samples from other datasets which may inform the distribution of the biotope and whether reef habitat is present have also been reviewed and incorporated into the analyses.

For each area mapped as potential SS.SBR.PoR.SspiMx by Fugro (2016), a scoring assessment was made to gauge the confidence of the mapped area as part of the current study. This assessment considered how the feature was mapped and the supporting evidence. A positive score was given to all areas initially as these have been identified by expert interpretation and judged to be areas of seabed which potentially support SS.SBR.PoR.SspiMx. If the area was substantiated by a sample station which supported this assignment, then the confidence was increased as the likelihood the area supported SS.SBR.PoR.SspiMx is increased. Conversely if samples from the same location, collected at different times, were found to contain data which does not consistently support SS.SBR.Por.SspiMx, then the likelihood that the area supports SS.SBR.PoR.SspiMx is diminished and the confidence is reduced. Both video and grab sample data were used where possible.

Figure 9 shows the areas identified by Fugro (2016) as potential SS.SBR.PoR.SspiMx, coloured to show level of confidence for each area. It can be seen that Figure 9 shows some areas mapped with high confidence, but others mapped as the potential SS.SBR.PoR.SspiMx biotope without supporting sample data from current or historic records have lower confidence.

Further review of sample data and supporting evidence has therefore been undertaken and the habitat maps refined.

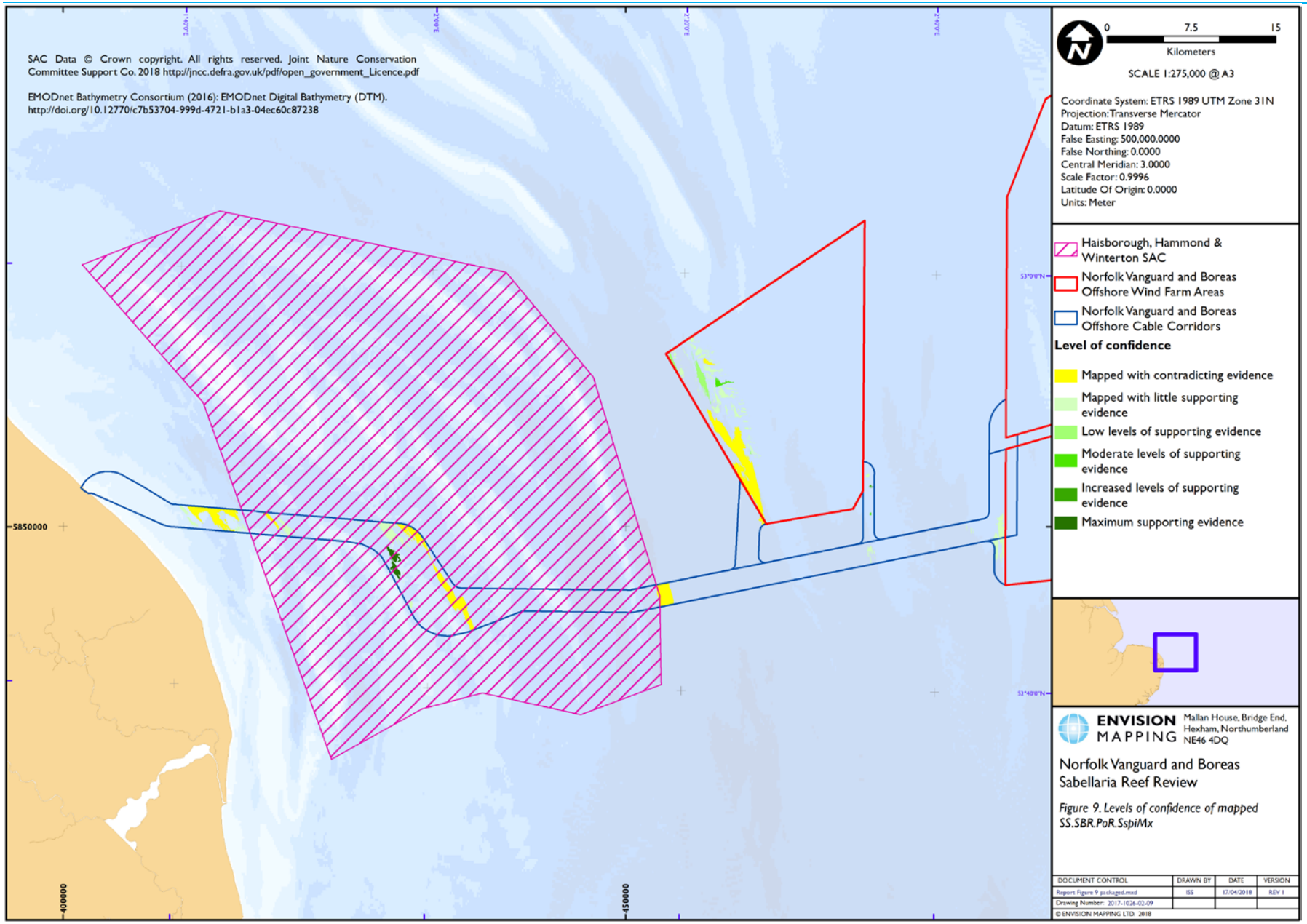

Figure 9.
Levels of confidence of mapped potential SS.SBR.PoR.SspiMx

2.3.1. Reef assessment of samples

At several locations along the shared cable corridor and within the Norfolk Vanguard West site, Fugro (2016) analysis has attributed samples with the biotope SS.SBR.PoR.SspiMx and indicated the possibility of reef. This process of attributing samples to the *S. spinulosa* biotope and reef habitat appear to have taken a precautionary approach. An assessment of 'reefiness' was undertaken as part of the original analysis, with no samples having high 'reefiness' scores and only 2 having a medium level of reefiness and the biotope SS.SBR.PoR.SspiMx being attributed to samples regardless of 'reefiness'.

The data and imagery from these samples has subsequently been reviewed and where it was found Sabellaria abundance and 'reefiness' score were both low then samples were attributed with the habitat based upon the physical properties from the grab sample (PSA) following methods developed by Long, 2006 and used within UKSeaMap (McBreen & Askew, 2011)

Within the Norfolk Vanguard benthic characterisation report (Fugro, 2016) 8 grab and 6 video samples were attributed with the biotope SS.SBR.PoR.SspiMx, or as having low to medium 'reefiness'. Table 2 shows these samples along with comments from the current review process.

Table 2

Sample	Biotope (from grab sample)	Reefiness (from video sample)	Review	Mapped Habitat
01MS	SS.SBR.PoR.SspiMx	Low	Reefiness from video is low, and description is of clumps and sand inundation with moribund tubes. With 757 individuals within the grab this was not thought to constitute reef and was mapped according to the sediment properties	SS.SSa.CFiSa
02MS	SS.SBR.PoR.SspiMx	Unassessed	Grab sample contained only 40 individuals and with no supporting video this was not thought to constitute reef and was mapped according to the sediment properties	SS.SMu.CSaMu
03MS	SS.SBR.PoR.SspiMx	Not reef	Grab sample contained only 117 individuals and with video assessed as not reef this station was mapped according to the sediment properties	SS.SCS.CCS
19MS	SS.SSa.CFiSa	Low/Medium	With low numbers of individuals (64) and poor-quality video suggesting low relief and moribund tubes the habitat mapped was as attributed in the original analysis.	SS.SSa.CFiSa

Sample	Biotope (from grab sample)	Reefiness (from video sample)	Review	Mapped Habitat
25CR	SS.SCS.CCS.MedLumVen	Low	Grab sample contained only 145 individuals and attributed to the 'MedLumVen' biotope. Video assessment indicates low reefiness with only clumps and crusts the habitat mapped was as attributed in the original analysis.	SS.SCS.CCS
40CR	SS.SBR.PoR.SspiMx	Medium	Grab sample contains very high numbers of individuals (3773) and video supports medium reef in places therefore mapped as SS.SBR.PoR.SspiMx and considered as Sabellaria reef	SS.SBR.PoR.SspiMx
62CR	SS.SBR.PoR.SspiMx	Not reef	Grab sample contained relatively low numbers (294) of individuals and with video assessed as 'not reef' this station was mapped according to the sediment properties	SS.SMx.CMx
64CR	SS.SBR.PoR.SspiMx	Not reef/Low	With video and grab (1255 individuals) both suggesting the possibility of low 'reefiness' this sample was attributed with the biotope allocated in the original analysis and considered as low reefiness	SS.SBR.PoR.SspiMx
65CR	SS.SBR.PoR.SspiMx	Low	With video and grab (2464 individuals) both suggesting the possibility of low 'reefiness' this sample was attributed with the biotope allocated in the original analysis and considered as low reefiness	SS.SBR.PoR.SspiMx
67CR	SS.SBR.PoR.SspiMx	Not reef	This sample station has 1180 recorded from the characterisation survey and lower numbers from the zone wide survey (2). The video sample was inconclusive but suggested reef habitat therefore precaution was used and the sample attributed with the SS.SBR.PoR.SspiMx biotope.	SS.SBR.PoR.SspiMx

Ground truthing data (video, grab and trawl) from Inner Dowsing, Race Bank and North Ridge along with Haisborough, Hammond and Winterton survey data had been assessed for 'reefiness' using an assessment based on recommendations made by Foster-Smith and Hendrick (2006) and Gubbay (2007), Data from the Vanguard Characterisation Report (Fugro, 2016) had been assessed using the same

recommendations (Figure 8). Additionally, preliminary data collected as part of a CEFAS Survey (code CEND 11/16) (McIlwaine *et al*, 2017) has been assessed and investigated to determine the status of reefs in the surrounding area but advice from MMO suggests these preliminary data are removed from reef prediction model and therefore these data have not been included in this further assessment. Once data have been finalised it is possible these could be incorporated in the process to better determine the likely extents of *S. spinulosa* reef.

Sample data collated as part of Cooper & Barry, 2016 and from East Anglia Zone Environmental Appraisal (MESL, 2012) were reviewed by assessing the numbers of Sabellaria individuals recorded within samples.

All samples were used to assess the confidence in any area mapped as the biotope SS.SBR.PoR.SspiMx in the original analysis (Fugro, 2016). Where elevated numbers of Sabellaria were found or samples were identified as reef by the original authors these added confidence to any mapped areas.

In addition to reviewing the current mapped habitat extents, all available sample data, and ensemble mapping techniques (see section 2.5) were used to build habitat distribution maps of the area. This method uses multiple mapping processes, with the aim of improving map performance and outputs by combining the results of several mapping techniques to produce a refined 'ensemble map'.

The resulting maps are compared and where there is consensus, this builds confidence in the mapped areas and enables a final, refined map to be produced which is supported by available datasets providing a greater level underlying confidence. This map incorporates appropriate levels of precaution in terms of how the sample data are assessed and used within the mapping processes. Any ambiguous or uncertain areas were also mapped using the original (Fugro, 2016) precautionary approach.

2.4. Integration of sample and physical data for mapping

The ground truth point data were buffered to create a training area of 25m radius around each point and these areas associated with the appropriate habitat category.

The integration analysis was performed in the GIS and image processing software *Idrisi Taiga*. The training areas were used to extract values from each of the geophysical layers that could be associated with the biological habitat classes. These values were used to create a statistical 'signature' for each class.

These signatures were then applied to the whole geophysical data set. One method of classifying images is to use a maximum likelihood classifier, whereby each grid cell/area is assigned to the class to which the grid cell has the highest probability of membership. This works well where the data in the images provide sufficient discrimination. The initial outputs indicated a lack of discriminatory power that resulted in a high level of confusion between classes or classes attributed to incorrect locations; so, to increase the power of discrimination, probability mapping was introduced to better define the areas where habitats could occur.

The point sample data were used to derive *probability images* which reflect the spatial trends of the occurrence of habitats across the cable corridor and OWF area. These images express the likelihood of finding a particular habitat or biotope in an area based on prior knowledge of their distribution from the ground truth data.

Incorporating these probability images into a maximum likelihood model enables the spatial trends and knowledge from the sample data influence the mapping processes and does not rely on the interpretation of the geophysical data alone. This improves the mapping process as there can be confusion between habitats identified purely from the properties of geophysical data alone. A schematic diagram illustrating the main stages in the analytical process is shown in Figure 10.

Two datasets were used to introduce the probability of a habitat occurring in a certain location. Primarily, the dataset collected as part of Norfolk Vanguard Benthic characterisation were used, these data were collected as part of the same survey campaign as the geophysical datasets that are contemporary both spatially and temporally. Secondly, the data from other surveys were introduced which enables samples which are not coincident with the geophysical datasets to influence the mapping process, as habitat probabilities from sample stations close to the cable corridor and OWF can 'bleed' in the area.

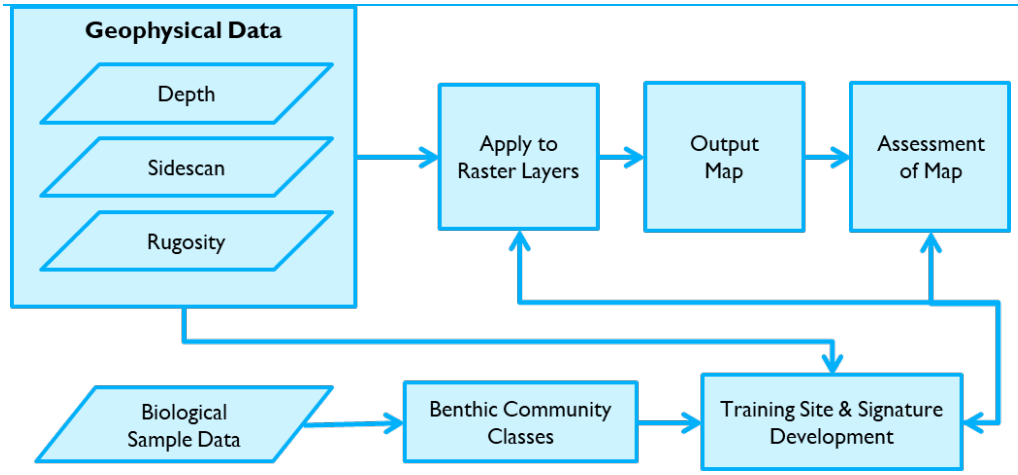

Figure 10.
Schematic diagram outlining the main stages in the modelling of the distribution of biotas classes

2.5. Existing distribution maps

In addition to the distribution of 'potential SS.SBR.PoR.SspiMx' identified within the Vanguard Characterisation Report (Fugro, 2016) information from the EC REC have been provided by Natural England and are incorporated within this current assessment.

The EC REC data provides two versions of reef extent, the first is the likely extent as determined by acoustic records using methods after Limpenny *et al.* (2010), the second being 'bottom-up" modelling which identifies areas of 'dense Sabellaria' which are described as '*forming extensive reefs*' and 'moderately dense Sabellaria' described as '*areas with crusts and patches rather than extensive reef*' but are considered by Natural England to have the potential to support reef due to the high presence of *S. spinulosa* individuals.

2.6. Ensemble Mapping

A range of mapping processes have been applied which employ the principles shown in Figure 10. these range from image processing classification systems to topographic analysis classification, and rule-based modelling. Current opinion (Lillis *et al.*, 2016, Diesing & Stephens, 2015) is that there is no best process to use, with each having merits and downsides. To accommodate this and also to provide an additional level of confidence in the mapping processes a system of 'ensemble mapping' has been employed.

Ensemble mapping involves the creation of several iterations of benthic habitats and sediment maps each using a different mapping process. Whilst each of these iterations may have lower or higher confidences, or be more appropriate for specific habitats or datasets, they are combined and compared to produce benthic habitat and ecological characterisation of the area using the best current evidence base and as such be in line with regulatory guidelines. This process is summarised in Figure 11.

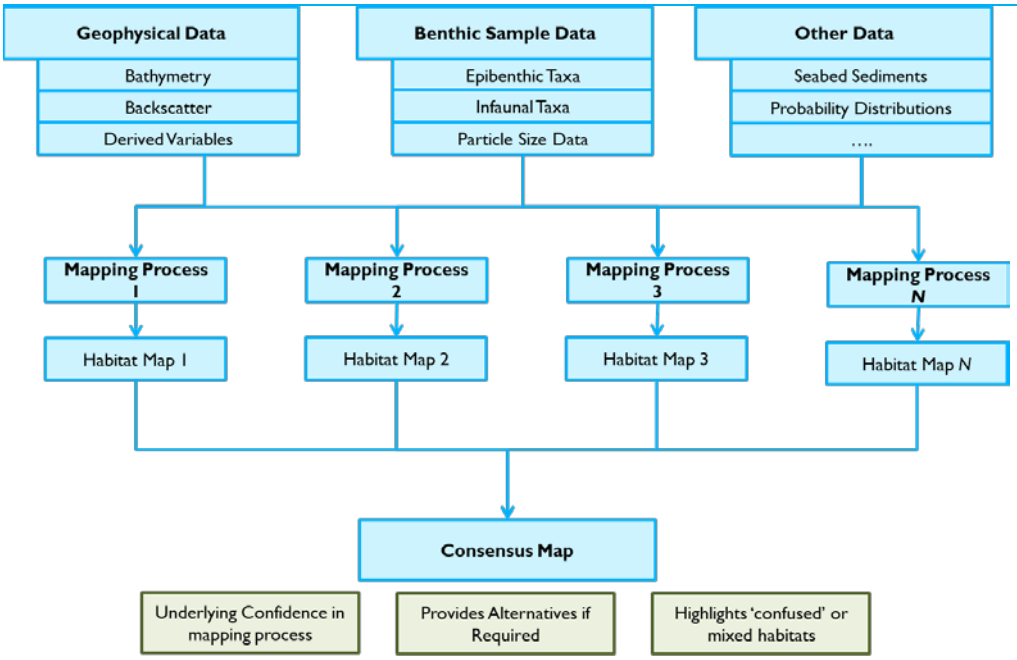

Figure 11. *Summary of data flow and outputs from the ensemble mapping process*

Five resultant maps were incorporated in to the ensemble mapping process:

1. The existing habitat map from Norfolk Vanguard Benthic characterisation
2. A newly derived habitat map using Norfolk Vanguard Benthic characterisation datasets
3. A newly derived map incorporating Norfolk Vanguard Benthic geophysical data with sample data from all other available datasets
4. The extent of *S. spinulosa* reef from EC REC derived from acoustic data interpretation
5. The extent of *S. spinulosa* reef from EC REC derived from 'bottom-up' modelling

The existing habitat map from Norfolk Vanguard Benthic characterisation was reclassified to represent the contemporary suite of habitats (Table 1) used within the process. Two classes, 'outcropping' areas and 'Nearshore pitted seafloor' were incorporated into the surrounding habitat SS.SMx.CMx or assessed as 'null' records respectively as these were not present in other mapping process or sample data and are not recognised habitat classes.

Once the five habitat maps were combined a consensus map was derived which shows the habitat category which is represented in the majority of maps. Where there is an equal probability of several habitat classes (i.e. five maps showing five different habitat categories), this was noted and the category from the habitat map produced from the Norfolk Vanguard Benthic characterisation datasets used.

2.7. Confidence Assessment

Confidence in the extents mapped by ensemble mapping process has been assessed using a scoring system, where all maps are in agreement then the area is give a high (5) value and when 4 maps are in agreement and one is contrary then a value of 4 is attributed to the mapped area etc. until where only one map suggests *S. spinulosa* reef then the lowest confidence score of 1 is given.

This confidence score does not consider the underlying confidence or accuracies for each of the maps used but is a measure of agreement indicating concordance between a variety of mapping techniques and processes. Where all mapping methods agree, this can be considered a high confidence area and where the mapping method results contradict each other these areas can be considered as lower confidence areas.

The implication of this could be that areas of high confidence should be avoided within any development plans and areas of low to moderate confidence could be targeted for additional investigation prior to any development.

2.8. Assumptions

Several assumptions have been made within this review which should be considered when utilising any data or outputs. Habitat classes attributed to samples were considered to be accurate and whilst the process of how they were assigned has been reviewed the underlying dataset have not been queried extensively. Likewise, the results from video footage analysis have been relied upon, a review of still images and descriptions and analyses has been undertaken as part of this study but original video interpretation (Fugro, 2016) has been used. The original characterisation habitat map has been used as supplied and the method of how this was produced has been reviewed but not critically assessed. Within the mapping processes there are underlying statistical processes and parameters which have inherent assumptions and caveats, and these have been accepted and incorporated within any outputs.

3. Results

The main outputs of this review are a series of maps showing the distribution of habitats from the various mapping methods, with a consensus map showing the distribution of marine habitats from the current understanding of the area in question.

Figure 12 shows the distribution of marine habitats from the original characterisation study (Fugro, 2016) with the habitats standardised to a common level. This map has been produced by expert interpretation from geophysical data along with grab and video data. The map has been reviewed by using sample data to assess the certainty in the mapped areas (Section 2.3). As the underlying levels of confidence in the map are relatively low, data has been reworked and assessed to produce refined maps.

Figure 13 is derived from the same sample and geophysical data as Figure 12 but also incorporates the level of probability of each habitat being located throughout the mapped area. This map shows patterns in habitat distribution similar to that found in the original habitat map but with a reduced area of *S. spinulosa* habitat and introduces the habitat of circalittoral muds and sandy muds which is supported by the PSA data from grab samples. There are also some variations in the distribution of sands and coarse sediments which appear to be associated with sand wave features.

Figure 14 shows a habitat distribution map derived using a large set of sample data which have been allocated to habitat type based on the properties of the sediment within the samples, alongside the site specific data used to generate the preceding habitat maps (Figure 12 & Figure 13). Introducing these additional data does alter the distribution of habitats within the Vanguard West OWF area, in that the seabed is mapped as a sandy habitat (SS.SSa.CFiSa) where other maps have been predominantly coarse sediment-based habits (SS.SCS.CCS and lower hierarch levels). This change is explained by the use of the PSA data to classify the samples with a habitat category (as described in Long, 2006). This, along with the increased number of samples, overrides coarse habitats and biotopes which have been allocated based upon the biological communities which occur within the samples which is in line with current advice for using the marine habitats classification. (Lillis *et al.*, 2016). The effect on the mapping process is discussed below.

Figure 15 shows the distribution of habitats which best represents the current datasets. The map is derived from the ensemble mapping process and combines the outputs of the previous three maps (Figure 12, Figure 13 and Figure 14). The map shows the Norfolk Vanguard West OWF area to be dominated by coarse sediment communities (SS.SCS.CCS and lower hierarchy levels) with sandier (SS.SSa.CFiSa and lower hierarchy levels) within sand wave systems. The western edge of the OWF area appears to be influenced by the silt content found within the seabed, and sandy mud habitats are predicted based upon the silt content of the grab samples found in this area. There are some areas which are mapped as SS.SBR.PoR.SspiMx biotope, which are found on the edges of large sand waves and are supported by the presence of large numbers (>750) of *S. spinulosa* in the grab sample and the video footage information which suggests reef but with a low 'reefiness' score. It may be that these are patches of *S. spinulosa* which grow to elevated levels above the seabed but, due to the migration of sand waves in the area (ABPmer, 2017, Appendix 7.1 of the Information to Support HRA report (Document 5.3)), are subject to inundation by sediment and do not form extensive or elevated reef systems.

The export cable corridor which leads from the eastern boundary of the Norfolk Vanguard West OWF area also has SS.SBR.PoR.SspiMx biotope predicted in several locations and these predictions are supported by samples with very high numbers (1000-2400 individual per sample) of *S. spinulosa*. Here the video data show low levels of 'reefiness' as the structures are not highly elevated and are patchy in structure.

These areas should therefore be considered as *S. spinulosa* reef but with low levels of 'reefiness'.

The export cable corridor has coarse sediment and sandy habitat throughout its length which are occasionally interspersed with softer sediments. Towards landfall the seabed is of mixed substrate with patches of coarse sediments. *S. spinulosa* reefs are found to occur within the 'dog-leg' section of the shared Norfolk Vanguard and Norfolk Boreas cable corridor. An oval shaped reef is predicted with medium to high certainty and is supported by grab samples with over 3700 individuals within a sample and video evidence supporting a medium 'reefiness'. To the east of this area there are elongated sections of SS.SBR.PoR.SspiMx biotope which are supported by elevated numbers of *S. spinulosa* within samples but are poorly supported by video evidence. The abundance of *S. spinulosa* are high (2000-3000 per sample) but the data are from records collected in 2009. With this in mind these areas should be considered as potential reef habitat as *S. spinulosa* reefs are known to be ephemeral and not permanent structures.

Figure 16 is a map which represents the underlying confidence in the ensemble map which has been produced. This confidence is based upon the number of times each of the maps are in agreement. Habitat areas which are consistently mapped the same having the highest confidence and those which are confused throughout the maps having the lowest confidence. The attributed level of confidence should be considered when using the distribution of habitats within any decision-making processes.

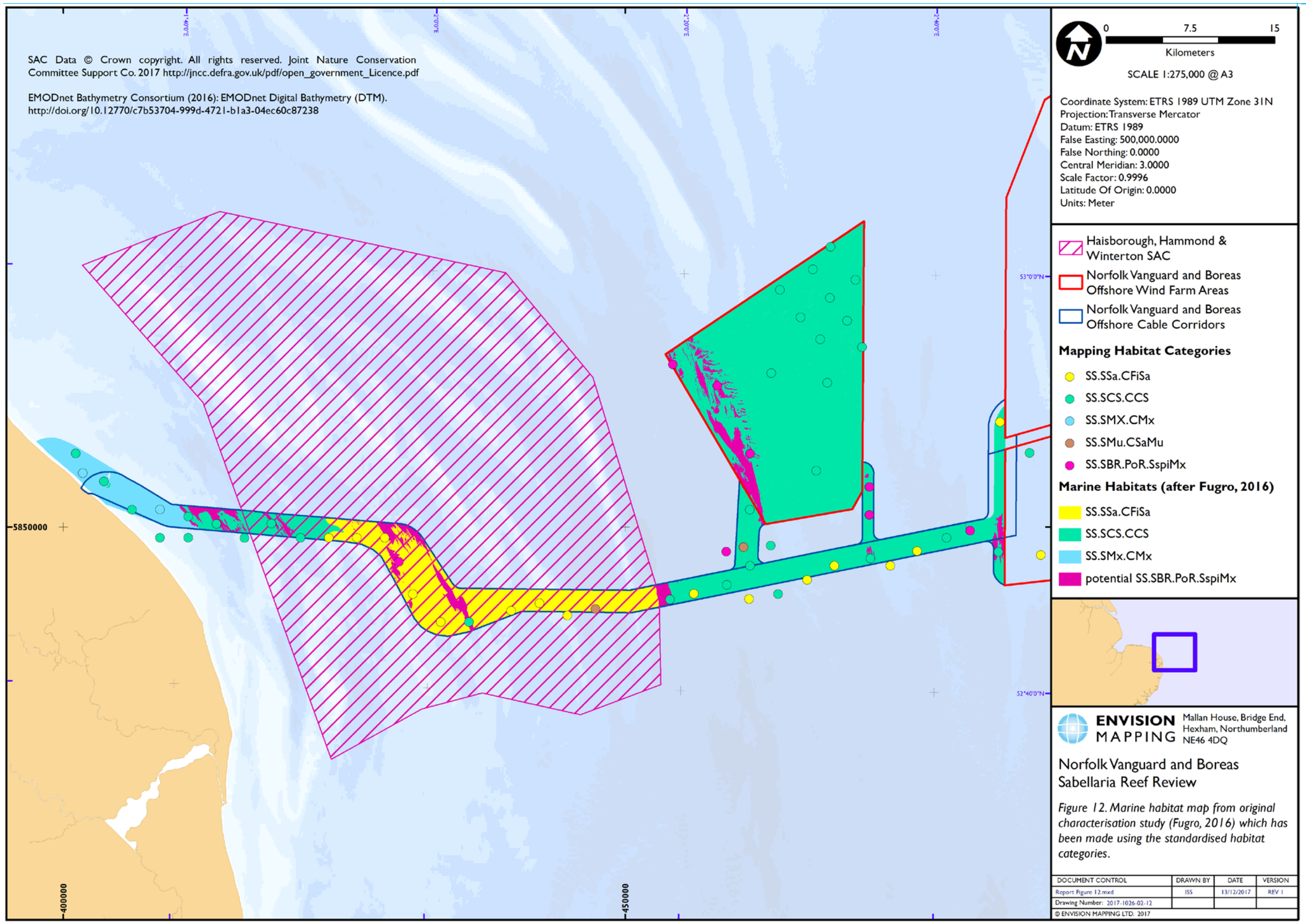

Figure 12.
Marine habitat map from original characterisation study (Fugro, 2016) which has been made using the standardised habitat categories.

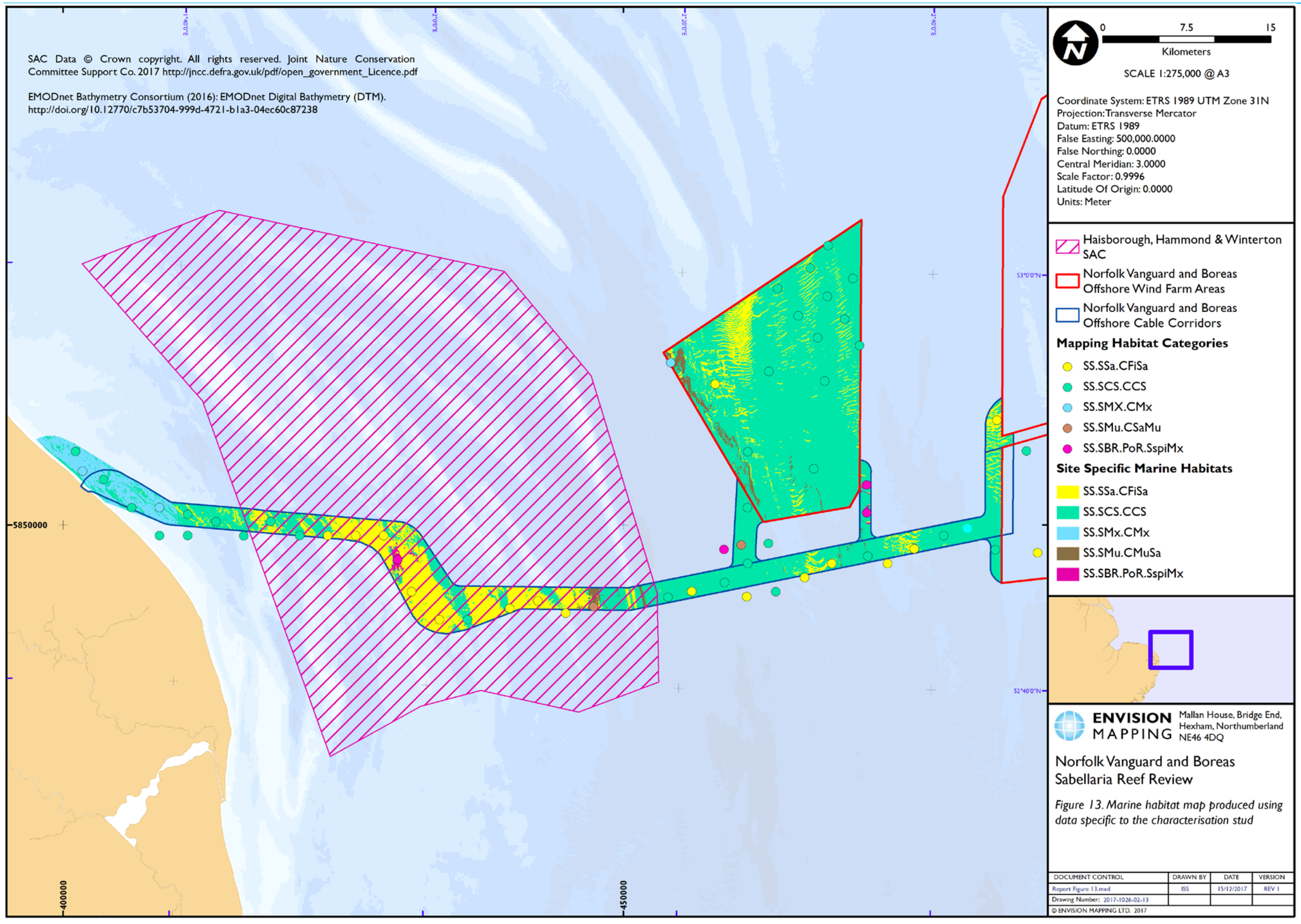

Figure 13.
Marine habitat map produce using data specific to the characterisation study

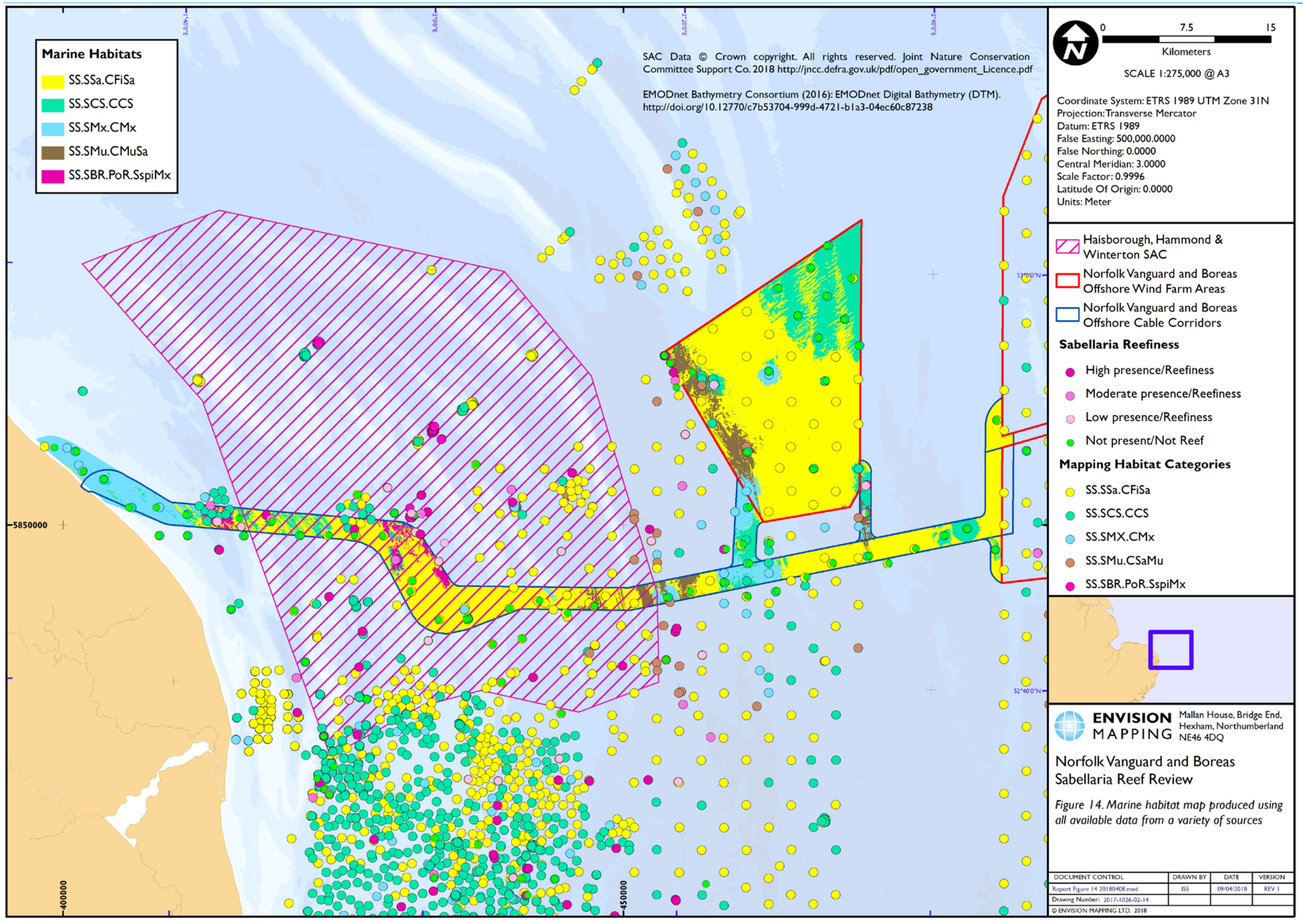

Figure 14.
Marine habitat map produced using all available data from a variety of sources

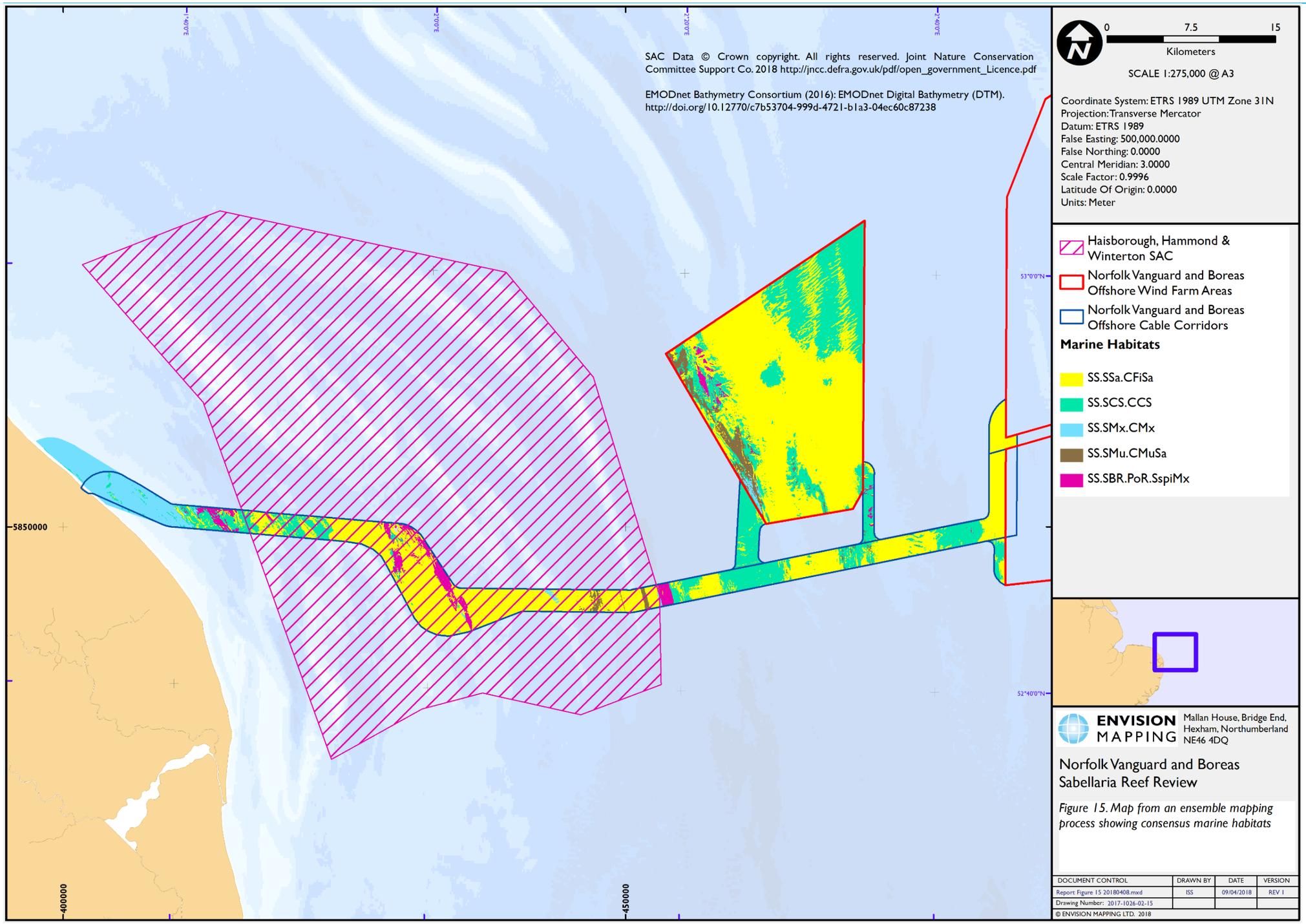

Figure 15.
Map from an ensemble mapping process showing consensus marine habitats

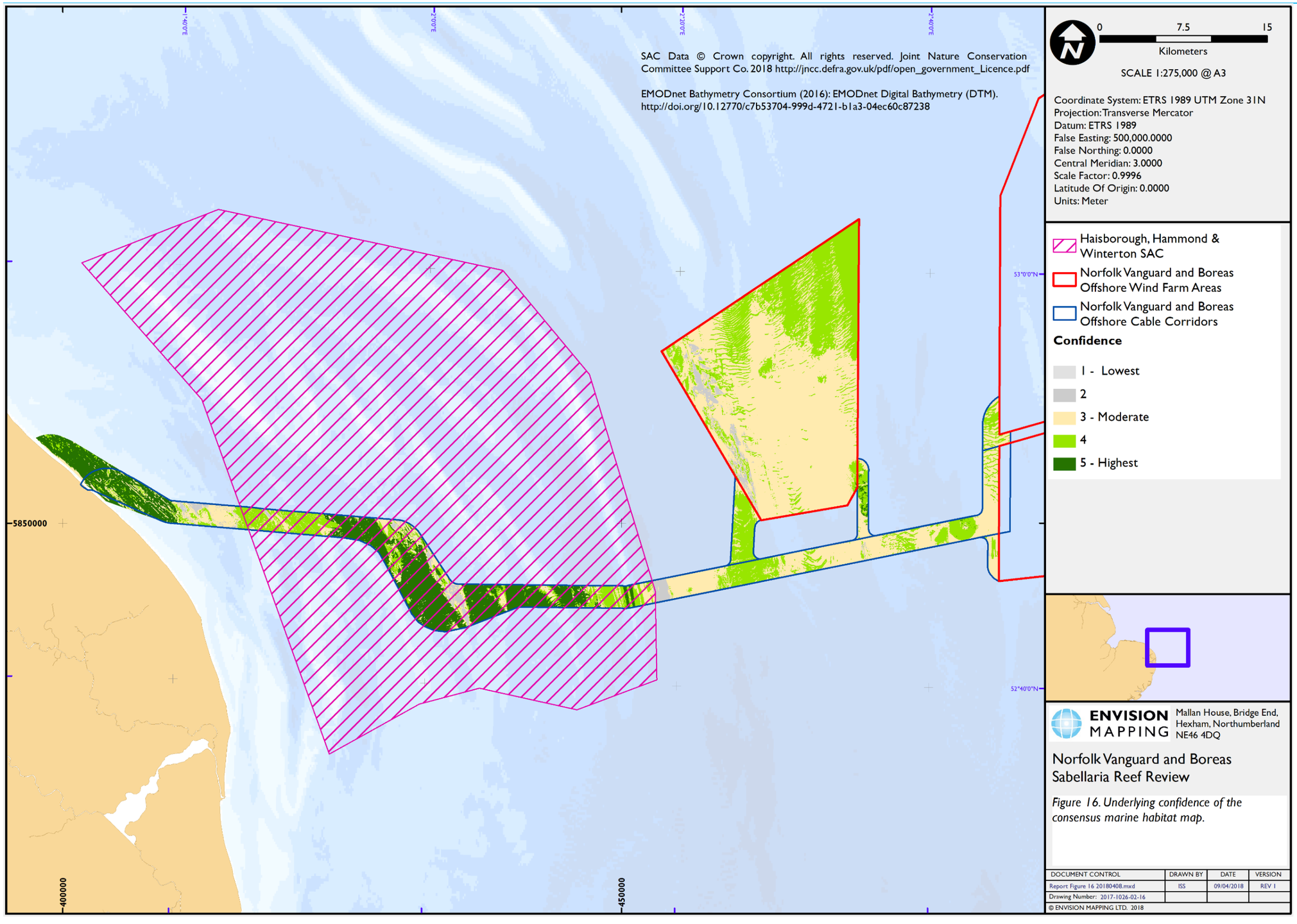

Figure 16.
Underlying confidence of the consensus marine habitat map.

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3.1. Current distribution of *Sabellaria spinulosa* reefs

The aim of the review was to focus on the distribution of the SS.SBR.PoR.SspiMx biotope and *S. spinulosa* reef. Therefore, the likely distribution of SS.SBR.PoR.SspiMx biotope has been mapped separately with supporting data shown (Figure 17).

In order to map the distribution of *S. spinulosa* reef the underlying confidence levels for the areas mapped as SS.SBR.PoR.SspiMx biotope were used. The areas of SS.SBR.PoR.SspiMx biotope and the confidence associated with them have been mapped separately (Figure 18 to Figure 22. Supporting sample data for these areas have also been considered and the 'reefiness' associated with them included when assessing whether an area is considered to be *S. spinulosa* reef. These maps indicate *S. spinulosa* reefs to occur in several locations throughout the cable corridor and Vanguard West OWF area.

Within the eastern entrance to the Vanguard West OWF Figure 18 shows *S. spinulosa* reef in two discrete areas with supporting sample data giving this area a low 'reefiness' score which should be considered within management or mitigation processes. The grab samples contained elevated number of individuals (>1000) but video sample data showed aggregations of *S. spinulosa* tubes had low relief and patchy distribution.

Within the 'dog leg' section of the shared Norfolk Vanguard and Norfolk Boreas cable corridor, Figure 19 shows *S. spinulosa* reef to occur and this is supported by grab sample data which contained the highest number of individuals (3773) within the shared Norfolk Vanguard and Norfolk Boreas cable corridors or Norfolk Vanguard OWF area and video data which indicated the area to have patchy 'reefiness', with areas of medium 'reefiness' containing aggregations of *S. spinulosa* tubes raised 5-10cm from the seabed and forming continuous aggregated structures in places. Other low reefiness areas are also encompassed in this area with consolidated clumps of *S. spinulosa* tubes raising up to 10cm from the seabed. An area identified as reef extends to the southern boundary of the cable corridor which has low/moderate confidence, within this area 5 samples, collected between 1998 – 2015, all have low abundance of *S. spinulosa* individuals (2 – 5 per sample) with no samples being classified as potential reef at any time. It would appear this area is unlikely to support *S. spinulosa* reef.

To the eastern boundary of the HHW SAC (Figure 20) a 'band' of *S. spinulosa* reef is predicated with relatively low confidence (Confidence score 2). This area appears to be predicted from interpretation of acoustic data and sample points to the North and South of the area have been identified as supporting reef yet several coincident sample points over a period from 2007, 2010 and 2015 do not suggest reef occurs in this area.

As the cable corridor passes through the western boundary of the HHW SAC there are several areas (Figure 21) of potential *S. spinulosa* reef identified. One area is within the SAC boundary, which is supported by samples from 2009 (EC REC), has been scored having moderate to high presence of Sabellaria with a medium level of confidence.

West of the HHW SAC (Figure 21) there are areas of seabed which have been classified as *S. spinulosa* reef or 'moderately dense Sabellaria' which represents areas

with crust and patches of Sabellaria rather than extensive reef. These areas have a moderate (3) confidence score with sample data for the area showing one sample within the cable corridor (collected 2015) classified as low reefiness and a moderate reefiness sample from 2009 on the northern boundary of the cable corridor. *S .spinulosa* abundances are very variable (1 -145 per sample) and it is noted the area is subject to sand inundation (Fugro, 2016) suggesting this area may be ephemeral or patchy in nature.

Within Vanguard West OWF area (Figure 22) there are some areas which are mapped as SS.SBR.PoR.SspiMx biotope, which have relatively low confidence (Confidence score 2). These areas have been identified only by interpretation of acoustic data. However, the sample data for these do not show elevated numbers of Sabellaria. Sample data along the south-western edge of the OWF area do suggest *S. spinulosa* reef is likely to occur in this vicinity but the extent may be restricted. This area does appear to be a dynamic sand wave system (ABPmer, 2017) and it may be that due to the migration of sand waves clumps or crusts of Sabellaria are inundated by sediment and do not form extensive or elevated reef systems.

The ephemeral nature of *S. spinulosa* reefs and the variation in the forms it can take over time does mean that precise boundaries and 'reefiness' of any of the areas identified could change. Sample data supports this variation as samples collected from the same location two years apart can have vast changes in *S. spinulosa* numbers.

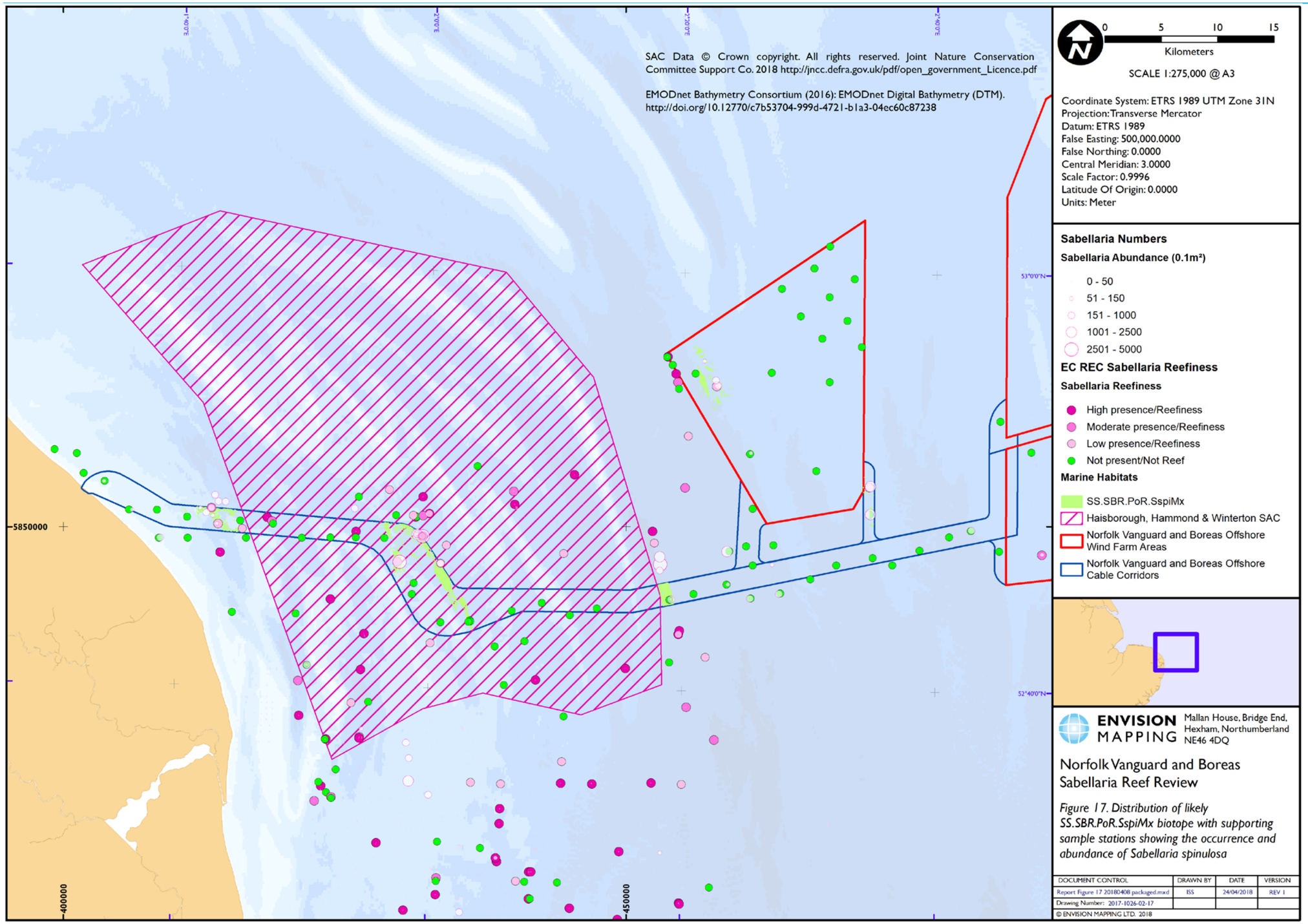

Figure 17.
Distribution of likely SS.SBR.PoR.SspiMx biotope with supporting sample stations showing the occurrence and abundance of Sabellaria spinulosa.

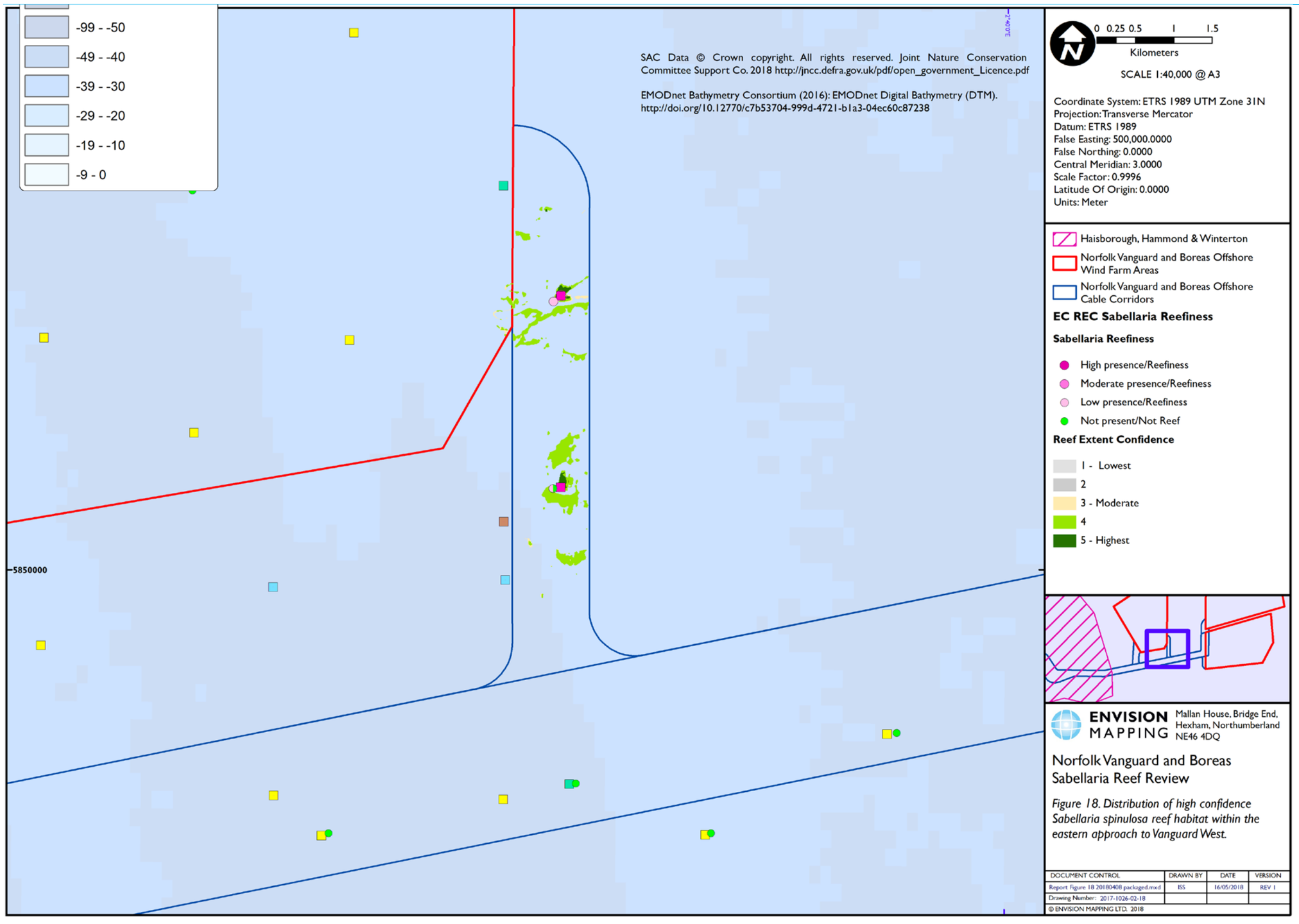

Figure 18.
Distribution of high confidence Sabellaria spinulosa reef habitat within the eastern approach to Vanguard West which are supported by low 'reefiness' video footage and elevated numbers of individual Sabellaria worms within grab samples.

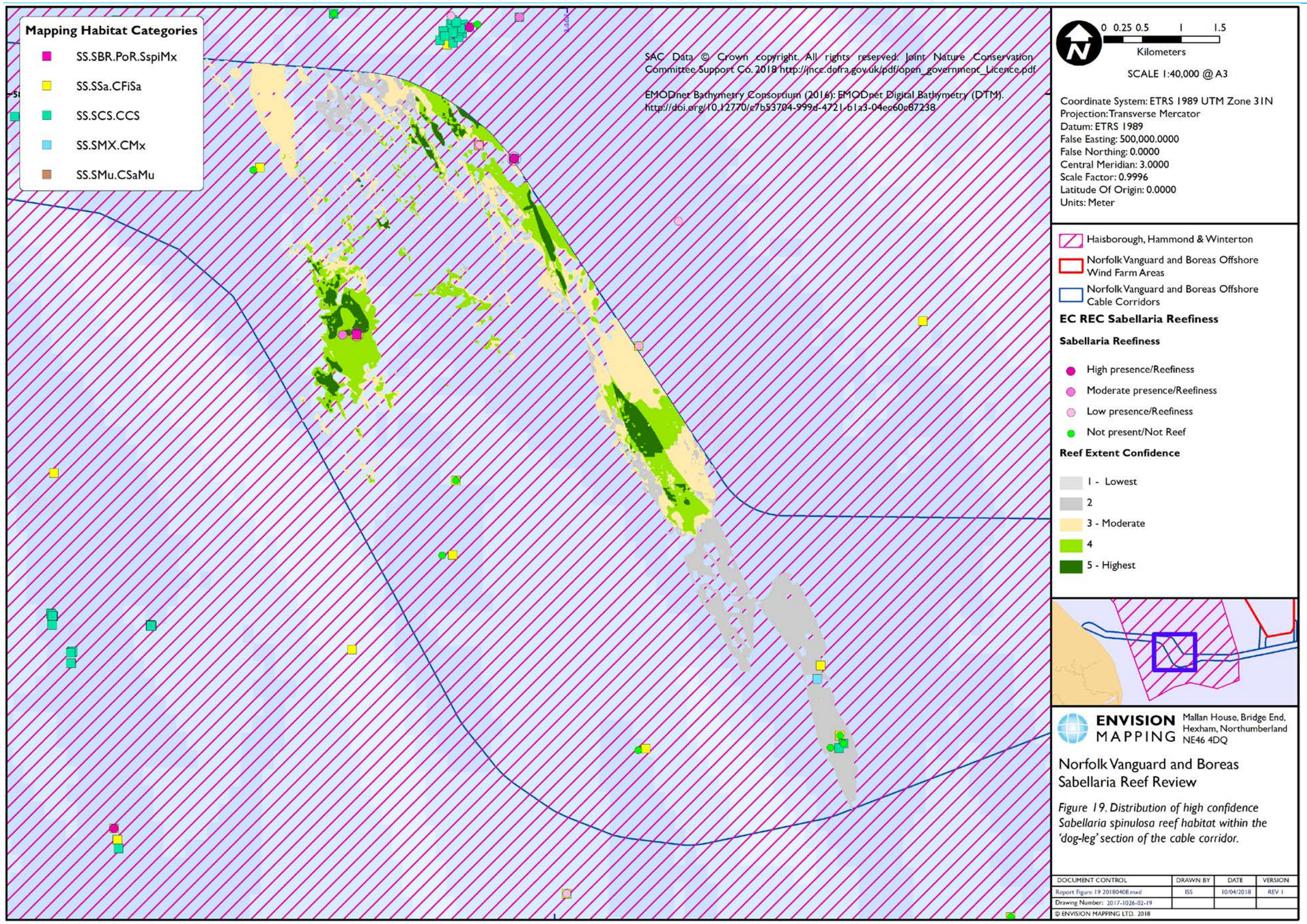

Figure 19.
Distribution of high confidence Sabellaria spinulosa reef habitat within the 'dog-leg' section of the cable corridor.

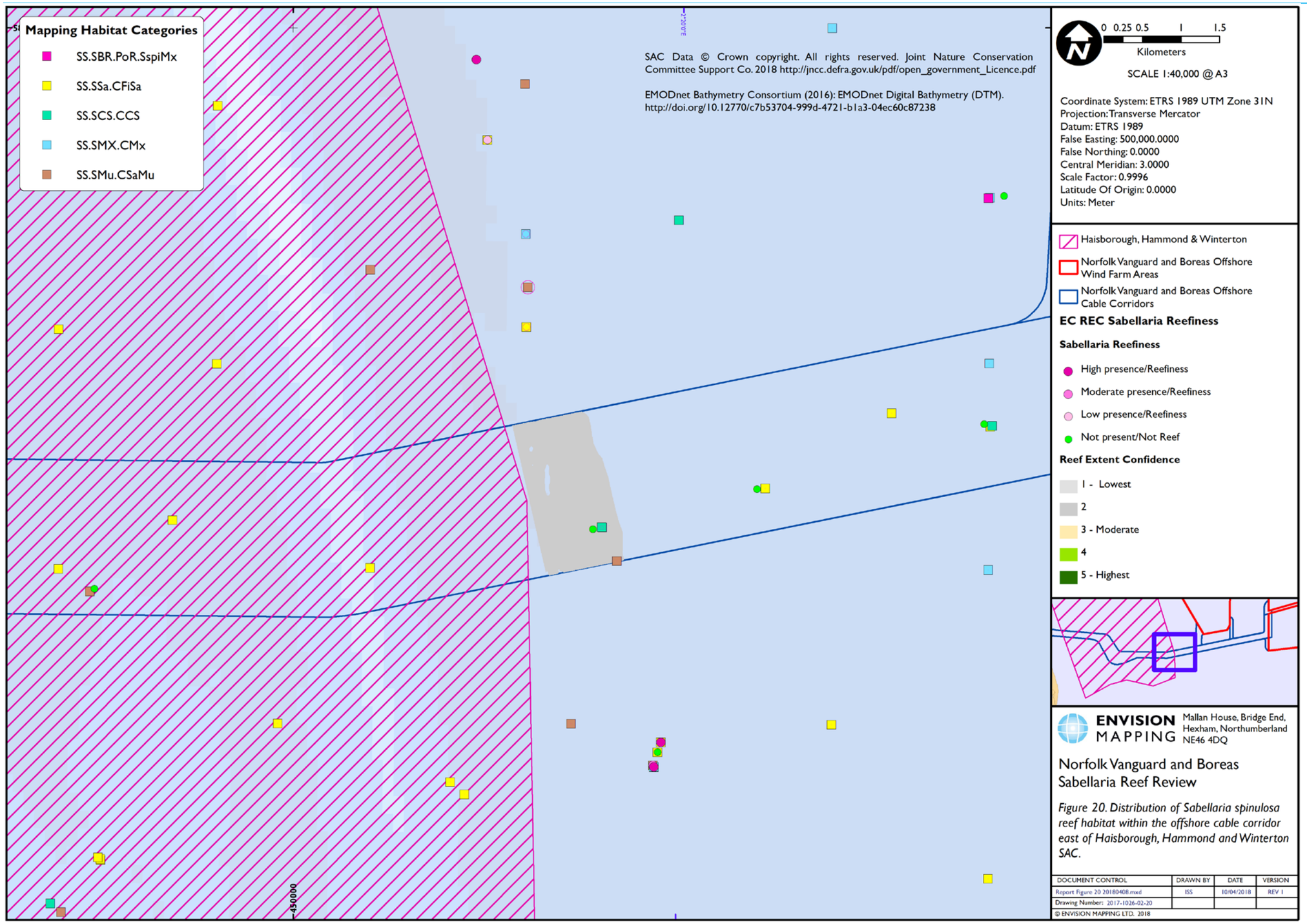

Figure 20.
Distribution of Sabellaria spinulosa reef habitat within the offshore cable corridor east of Haisborough, Hammond and Winterton SAC

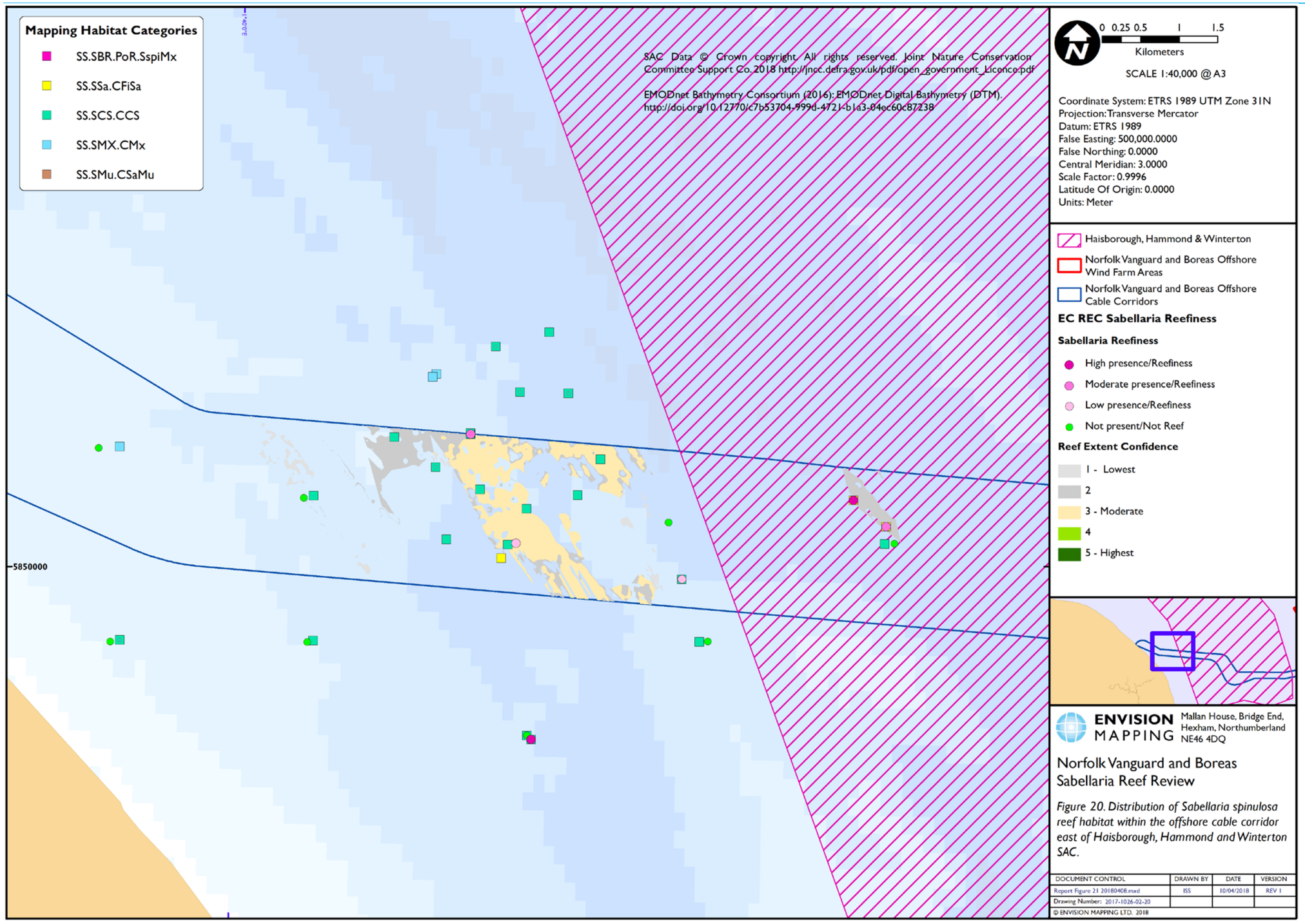

Figure 21.
Distribution of Sabellaria spinulosa reef habitat within the offshore cable corridor west of and within Haisborough, Hammond and Winterton SAC

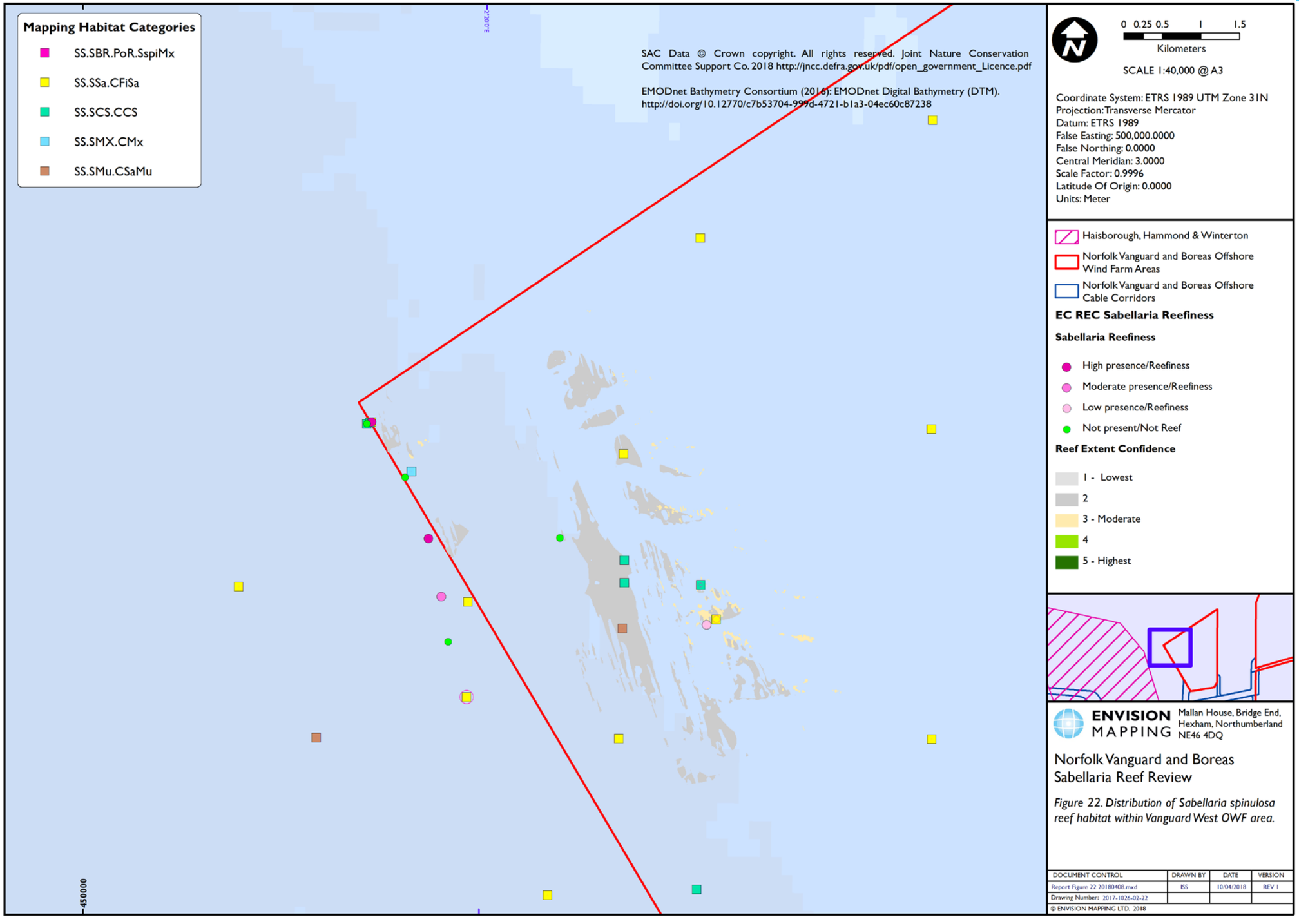

Figure 22.
Distribution of Sabellaria spinulosa reef habitat within Vanguard West OWF area.

4. Summary

The initial biotope mapping within the cable corridors and Norfolk Vanguard OWF (Fugro, 2016) showed extensive areas of potential Sabellaria biotope (SS.SBR.PoR.SspiMx). From reviewing the data collected by Fugro, 2016 and augmenting this with other available data, the areas mapped as potential Sabellaria biotope have been refined to more precise and spatially constrained areas which are supported by sample data. These areas and samples have also been reviewed to identify where *S. spinulosa* reef may occur and the characteristics or 'reefiness' of these areas have been assessed.

Using ensemble mapping and incorporating regional sample data allows for a probabilistic approach to mapping to be incorporated along with the attribution of confidence to habitat areas which have been mapped. The ensemble mapping process does not dismiss any original findings or historic data but enables them to be used to build a better understanding of the marine habitats and their distribution. The use of this system will also allow for any future data to be incorporated and the habitat maps updated with any new data and information as it becomes available.

In general, the marine habitat distribution mapped currently shows very similar distribution to the habitats found within the Norfolk Vanguard characterisation study (Fugro, 2016), with some variations in sedimentary habitat types throughout the cable corridor and OWF area. Such variation can be expected in areas which are dynamic in terms of sediment movement.

The distribution of the biotope SS.SBR.PoR.SspiMx and *S. spinulosa* reef has been refined and now show areas which are considered low to medium in 'reefiness' and also highlights areas which are mapped with varying levels of confidence.

This definition of these areas within the Norfolk Boreas and Vanguard offshore cable corridor enables any future development within this area to consider this location and minimise any impacts and allow them to be mitigated appropriately.

Within the Haisborough, Hammond and Winterton SAC there are areas which have been identified by Natural England and JNCC to be managed as Annex I *S. spinulosa* reef (Natural England & JNCC 2018). Figure 1 shows the location of these areas in conjunction with the Norfolk Boreas and Vanguard offshore cable corridor.

S. spinulosa reefs are known to be unstable and ephemeral. They can form and reform rapidly, therefore, areas mapped as reef habitat should be considered alongside the confidence in the underlying mapping processes and in context with direct sample data which can provide supporting or contrary evidence for the likelihood of Sabellaria reef habitat being present.

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