Creating a EUNIS level 3 seabed habitat map integrating data originating from maps from field surveys and the EUSeaMap model

This report is available to download from http://jncc.defra.gov.uk/page-6655

1 Introduction

The present document describes the procedure used to create a EUNIS level 3 seabed habitat map integrating data originating from maps from field surveys and the EUSeaMap model. The work aims to create a map that presents the best available information on the distribution of EUNIS level 3 habitats at any location in UK waters. This dataset is required for, among other things, assessments of progress towards networks of marine protected areas (MPAs) in the UK and marine spatial planning.

The work was originally planned for quarter 4 of 2013-2014 but brought forward to quarter 3 due to the product being required for an assessment of progress towards an MPA network. Consequently, some habitat maps that were produced as part of the Marine Conservation Zones (MCZ) verification surveys in 2012 & 2013 were not ready for inclusion. These maps will be incorporated into future revisions of the product.

1.1 Specification for end product

The aim was to produce a single map layer displaying the best quality EUNIS level 3 data at any location. Furthermore, the process for producing the layer needed to be:

- Repeatable;
- Transparent;
- Easy to explain and understand;
- Objective;
- Fully documented;
- Appropriate for EUNIS level 3 habitats; and,
- Appropriate for the UK, intertidal and subtidal areas.

Any location would show only a single value describing the habitat at EUNIS level 3, *i.e.* no overlapping polygons leading to multiple possible values at a location. The data at any location should be the best available to describe the EUNIS level 3 habitat type (i.e. the most likely to be correct).

EUNIS level 3 habitats are listed in Appendix 1 and describe physical habitats classified using biologically meaningful parameters – substrate type, and additionally for rock: energy and biological zone. Therefore a method was created to choose data based on their ability to describe these physical variables.

1.2 Data sources

The data used to create the final product are habitat maps created from field survey data combined with broad-scale predictive habitat maps created by overlaying classified oceanographic models with a broad-scale substrate map (in this case, EUSeaMap (Cameron and Askew, 2011)). Because of these two descriptions of the data types, the final product has previously been referred to as the combined survey/model EUNIS level 3 (L3) map.

Maps from bespoke field surveys: Through JNCC's obligations to assess and report on benthic habitats at a UK scale, it retains copies of the majority of the seabed habitat maps that exist for the UK. These maps were produced at a variety of spatial scales and describe habitats and biotopes at different levels of detail within the EUNIS habitat classification; they have also been produced using a variety of methods. In total, 209 survey-derived maps were combined in this present process with the map from the EUSeaMap habitat model.

Broad-scale predictive map: the EUSeaMap project produced a seabed habitat map of the entire UK marine area, including the extended continental shelf area, as part of a map covering the wider North Sea and Celtic Sea (Cameron and Askew, 2011); the project also produced equivalent maps for the Western Mediterranean and the Baltic Sea. It was produced by overlaying full-coverage datasets of the physical variables substrate type, current energy, wave energy, depth and light attenuation, matching the conditions at each location to the corresponding definitions of each EUNIS habitat type. This process generates a map that is consistent across large areas in terms of spatial scale and methods used; however, it is usually at a coarser spatial scale ('pixel' resolution of ~250m) than survey-derived maps and does not use all of the information available in all locations in the interest of consistency. EUSeaMap currently represents the most recent, up-to-date broad-scale predictive EUNIS habitat map for UK waters as it has been updated more recently than its predecessor UKSeaMap 2010 (McBreen *et al*., 2011).

It is not the case that there is such an apparent strong distinction between these two techniques for creating habitat maps – technically all maps are models to some extent and the substrate data in the broad-scale model is itself interpreted from survey data. In fact, increasingly the sorts of maps that are being produced as a result of surveys (e.g. MCZ verification surveys) are substrate maps, which are combined with energy, light and depth models in order to obtain EUNIS level 3 codes (if rock is present, otherwise substrate is enough), which is roughly equivalent to the procedure used in the broad-scale predictive mapping (EUSeaMap). The major difference being the generally higher resolution of the bathymetric and substrate data from modern field surveys.

1.3 Previous work

JNCC created the first combined survey/model map to aid the identification of possible MCZs in 2011. In places survey-derived maps overlapped, and all of the subtidal survey maps overlapped the UK broad-scale predictive map that was used in this version - UKSeaMap 2010 (McBreen *et al*., 2011). The following decision process was applied to select which map to use in the event of an overlap:

- For an overlap between **UKSeaMap 2010 and an intertidal survey-derived map**, intertidal data were always given priority as UKSeaMap 2010 was only designed to model the subtidal marine environment and only extends into the intertidal area because of its coarse spatial resolution.
- For an overlap between **UKSeaMap 2010 and a subtidal survey-derived map**, a survey map required a MESH confidence* scores > 58 % to replace the UKSeaMap 2010 map.
- For an overlap between **survey-derived maps** (intertidal, subtidal or a combination), the map with the highest MESH confidence* score was used.

* The **MESH confidence assessment**[1] is a way of scoring a habitat map based on the quality of the remote sensing data, the ground-truthing data and the data interpretation techniques used to generate the map. These three criteria are assessed using a total of 15 (3 sets of 5) more specific criteria, which are scored and combined to provide a total score between 0 and 100. The score is a qualitative indication of the confidence one can have in using the map, **not** the probability (or likelihood) of the habitat class being present on the seabed at any location. To read more about the MESH confidence assessment method, see MESH Project (2008). A cut-off score of 58 % was applied because the survey techniques must have included a combination of remote sensing and ground truthing to derive the habitat map, suggesting that one can have some confidence in the habitat assignment.

[1]MESH Project (2008): www.searchmesh.net/Default.aspx?page=1635

1.4 Justification for a new combination procedure

For the 2013 version of combined survey/model map, a new procedure for assessing confidence and combining the various datasets was produced to address the following concerns raised about the method used in 2011 (Section 1.3 above):

1. The MESH confidence assessment method does not assess a map's ability to distinguish habitats of a certain level of detail; it is a more generic assessment that could be applied to a wide variety of maps. The process was originally designed to encourage best practice in habitat mapping by highlighting the factors that affect the quality of maps. At the time of its development in 2008, it focussed on a broad application to historic maps as recent survey data made up a smaller proportion of the total maps available. The method gives a higher score when biological data are used to develop a map, which in some cases can be misleading when reviewing a (physical) EUNIS level 3 map originally classified to level 5 or 6. This is because some sedimentary biotopes occur under one sediment type in the classification hierarchy while not being specific to one sediment type. If one of these biotopes were to be assigned based on species composition alone, while occurring on a different sediment type, the incorrect sediment type would be assigned when it is aggregated up to level 3. This issue is a known problem in the current EUNIS habitat classification that will be addressed in future updates.
2. The decision of whether to use a survey map or the broad-scale predictive modelled map at any position was based only on the survey map confidence, regardless of the confidence of the modelled map, meaning that:
    a. The confidence in the final combined map could not be described consistently everywhere – survey-derived map confidence was described using the MESH method; UKSeaMap 2010 confidence was described using a separate method.
    b. Variation in the confidence in UKSeaMap 2010 was not considered; therefore some low confidence areas of UKSeaMap may have excluded some overlapping survey maps that scored just under the 58 % cut-off, while high quality UKSeaMap 2010 data may have been excluded by some survey maps that scored just over the 58 % cut-off.
3. Although the MESH confidence assessment is straightforward, it takes some time to gain a full understanding of what it is actually showing. A common misconception has been that the percentage score represents the likelihood of finding a particular habitat at a location.

2 Three-step confidence assessment

2.1 Summary

The term “confidence” with regards to habitat maps can have many meanings and therefore should be qualified whenever it is used. Confidence is a term sometimes applied to the accuracy/uncertainty of the map based on external validation (testing the map with ground-truthing data that were not used in the map-making). This can be a very useful statistic but presents some challenges: data for validation are likely to be scarce, and the difference in spatial scales between a validation point (e.g. grab sample) and the map polygons means that mis-matches may be very common in spatially heterogeneous areas such as habitat mosaics.

The MESH confidence assessment delivers a confidence score that indicates the quality of the process used to make a biotope map and explains the relative reliability of different maps. However, because it refers to the mapping process as a whole, it does not give an indication of the probability (or likelihood) of any of the habitat classes in the map being present on the seabed at any location.

As a compromise between these alternatives, and to address the points in the previous section, a new confidence assessment was developed that produces a qualitative score indicating the likelihood of a particular habitat being correctly mapped within a study area. This was achieved by considering each of the MESH confidence criteria together with other factors affecting map quality and choosing those likely to have the greatest effect on the overall accuracy of the habitat assignments. Therefore, contrary to the original 15 criteria used in the MESH confidence assessment, the new confidence assessment method uses only three criteria:

1. Remote sensing coverage
2. Amount of sampling
3. Distinctness of class boundaries

Remote sensing coverage and *amount of sampling* are similar to the MESH criteria *remote sensing coverage* and *ground truthing density*, the former being deemed the most important factor in accurately delineating the class boundaries and the latter being the most important factor in accurately assigning the habitat type to each remotely sensed class. The *distinctness of class boundaries* criterion is not solely based on the techniques used to make the map and therefore does not have an equivalent in the MESH confidence assessment. It is rather a feature of the data and the particular habitats it surveyed, which are considered to have a large influence on the quality of the final map.

The three-step confidence assessment can be represented by a simple decision tree, in which the second and third questions depend on the answers to the previous questions, and the final score is a sum of the points awarded for each criterion (Figure 1; see Table 1 for more details on how each criterion is assessed). The final score will range between 0 and 4 with 4 representing the 'best' type of map. Note, however, that this is a qualitative assessment, therefore a score of 4 does not equate to a perfect or 100 % accurate map. The combinations of scores that can possibly result in each final score are shown in Table 2.

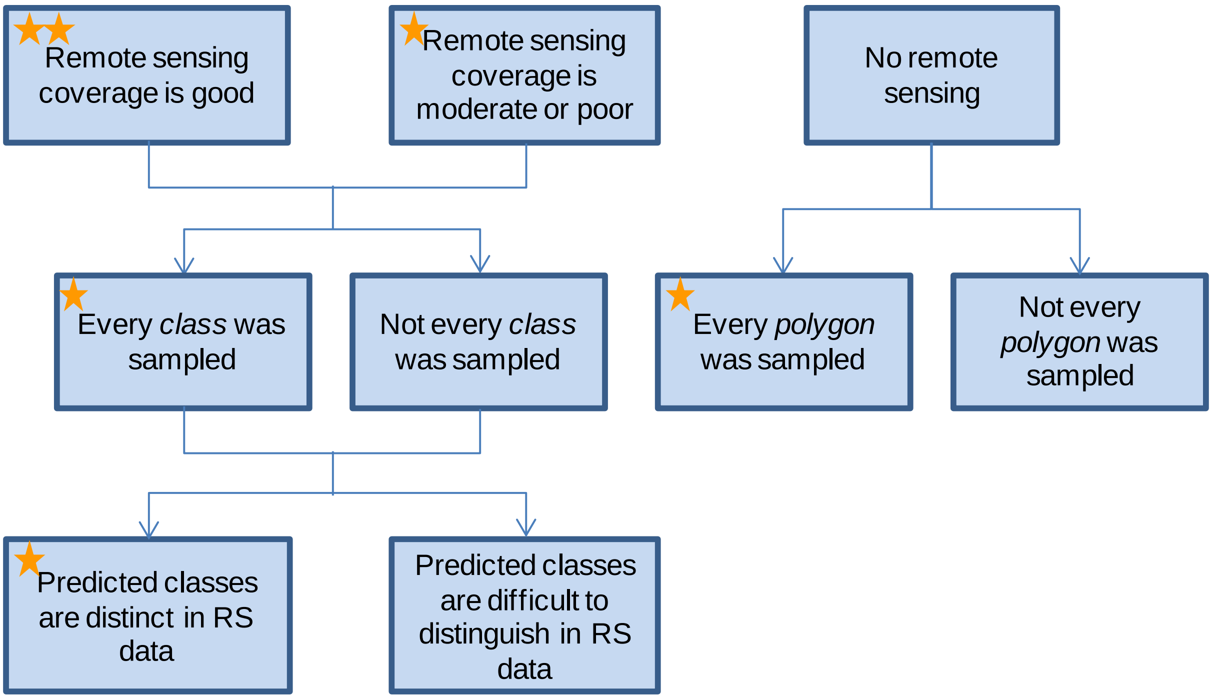


Figure 1: three-step confidence decision tree; the assessor starts at the top and follows the arrows. Stars/points are awarded according to the answers given and the final score is the sum of the stars/points.

Table 1: guidance on the application of the three-step confidence assessment method in scoring a EUNIS level 3 habitat map.

Name of criterion	Possible scores	Description	Sources of potential ambiguity
Remote sensing coverage	0, 1 or 2	How much of the study area is surveyed by remote sensing? 2 points: coverage is good 1 point: coverage is moderate or poor 0 points: no remote sensing used Remote sensing techniques include multi-beam or single beam echo sounder, side-scan sonar and aerial photography, among others.	There is some ambiguity in the amount of remote sensing that classes as “good” (2 points) and “moderate or poor” (1 point). This is to allow an element of expert judgement, based on the homogeneity of the seabed, the remote sensing technique used, whether the survey was inter-tidal or sub-tidal and any other factors considered relevant. A suggested rule of thumb is that over around 90% coverage is “good”.
Amount of sampling	0 or 1	Was there an adequate amount of sampling to identify every polygon? If there is any remote sensing data (i.e. if question one scores 1 or 2): 1 point: every/almost every class in the map was sampled. 0 points: not every class in the map was sampled. If there was no remote sensing (i.e. if question one scores 0): 1 point: every/almost every polygon in the map was sampled. 0 points: not every polygon in the map was sampled. Sampling techniques include grab sampling, photos, videos, shore survey and diver observation, among others.	“almost every class” is included here to allow the use of expert judgement in awarding a point for sampling. This question is more difficult for inter-tidal maps, as a surveyor can see a larger area around him/her. Therefore some judgement may be required about whether the density of sampling was adequate.
Distinctness of class boundaries	0 or 1	This question is only answered if there is remote sensing data (i.e. if question one scores 1 or 2). How easy is it to distinguish the classes in the remote sensing data and the boundaries between the classes? 1 point: the classes are distinct in the remote sensing data 0 points: some of the classes are difficult to distinguish in the remote sensing data.	An example of when it would be easy to distinguish classes is where the map only contains rock and mud, and the area has been surveyed with a multi-beam echo sounder. An example of when it would be difficult to distinguish classes is where the map contains subtidal coarse sediment, mixed sediment, and perhaps several different biotopes. Coarse sediment and mixed sediment are difficult to distinguish in acoustic remote sensing data, and biotopes are often impossible to distinguish.

Table 2: all combinations of scores that are possible under the three-step scheme. Maps with equal scores are therefore assumed to have roughly similar levels of confidence, regardless of the route through the decision tree.

Score	Remote sensing coverage	Amount of sampling	Distinctness of class boundaries
4	★★	★	★
3	★★		★
	★★	★	
	★	★	★
2	★★		
	★		★
	★	★	
1	★		
		★	
0			

2.2 Application for survey-derived data

The three-step confidence assessment was designed to be applicable to both survey-derived maps and maps from habitat models such as EUSeaMap. It also contains some flexibility to allow expert judgement to be used. However, the quantity of survey maps to assess necessitated a rule-based approach to be developed to obtain scores for the majority of the maps. Newly acquired maps, on the other hand, were assessed one-by-one according to the general guidelines in Table 1.

JNCC used the following rules to assess the majority of older survey-derived habitat maps, which already had MESH confidence scores:

1. *Remote sensing coverage* was originally derived from the MESH RemoteCoverage criterion; therefore a map gained:
   0 stars if MESH RemoteCoverage = 0
   1 star if MESH RemoteCoverage = 1 or 2
   2 stars if MESH RemoteCoverage = 3

2. *Amount of sampling* was originally derived from the MESH GTDensity criterion, therefore a map gained:
   0 stars if MESH GTDensity = 0 or 1
   1 star if MESH GTDensity = 2 or 3
   However, the MESH GTDensity scores were based on the original classes that were mapped; whereas for this we are interested in the EUNIS level 3 classes only. Therefore there will be some maps that score lower than they should.

3. *Distinctness of classes* requires a consideration of the type and number of habitats predicted, as well as the method of data collection. To simplify this process to allow many maps to be scored quickly, this criterion was assessed using the number of substrate types in a map as a proxy for the heterogeneity of the seabed and its ability to distinguish classes:
   0 stars if more than 2 different substrate types in map
   1 star if 1 or 2 different substrate types in map

The MESH criteria RemoteCoverage and GTDensity are described in Appendix 2 and MESH Project (2008).

2.3 Application for EUSeaMap data

The three-step confidence assessment method scores aspects related to the direct mapping of the seabed by survey. For the EUSeaMap model, this is equivalent to scoring the substrate map that fed into it, as the other data come from continuous light, depth and energy models (Cameron and Askew, 2011).

The scoring of the EUSeaMap substrate layer followed the same rules as described above for the scoring of survey maps. This was possible because a confidence assessment had already been undertaken for this substrate layer, using a modified version of the MESH confidence assessment (see the UKSeaMap 2010 Technical Report 3 (McBreen and Askew, 2011)).

JNCC found that the EUSeaMap substrate scores tended to be lower than expected in places because no areas of the map scored 3 for the MESH criterion RemoteCoverage even though there was full-coverage multi-beam echo sounder data in places.

To allow the analysis and removal of overlaps based on confidence scores (see next section) the EUSeaMap map was split into four layers of equal confidence scores, *i.e.* one layer containing all EUSeaMap data with a total confidence score of 1, one layer containing all EUSeaMap data with a total confidence score of 2, etc.

3 New procedure for combining maps

The new procedure for selecting the best map where two maps overlap follows a five-stage decision tree. The majority of the maps are sorted at stage 2, which is based on the three-step confidence assessment method. This is applied to all datasets, including all survey-derived maps (containing intertidal and/or subtidal data) and the broad-scale map based on the EUSeaMap model (Figure 2). The MESH confidence assessment score is also used, but only at a later stage and only if the new method of confidence assessment cannot distinguish between the overlapping maps.

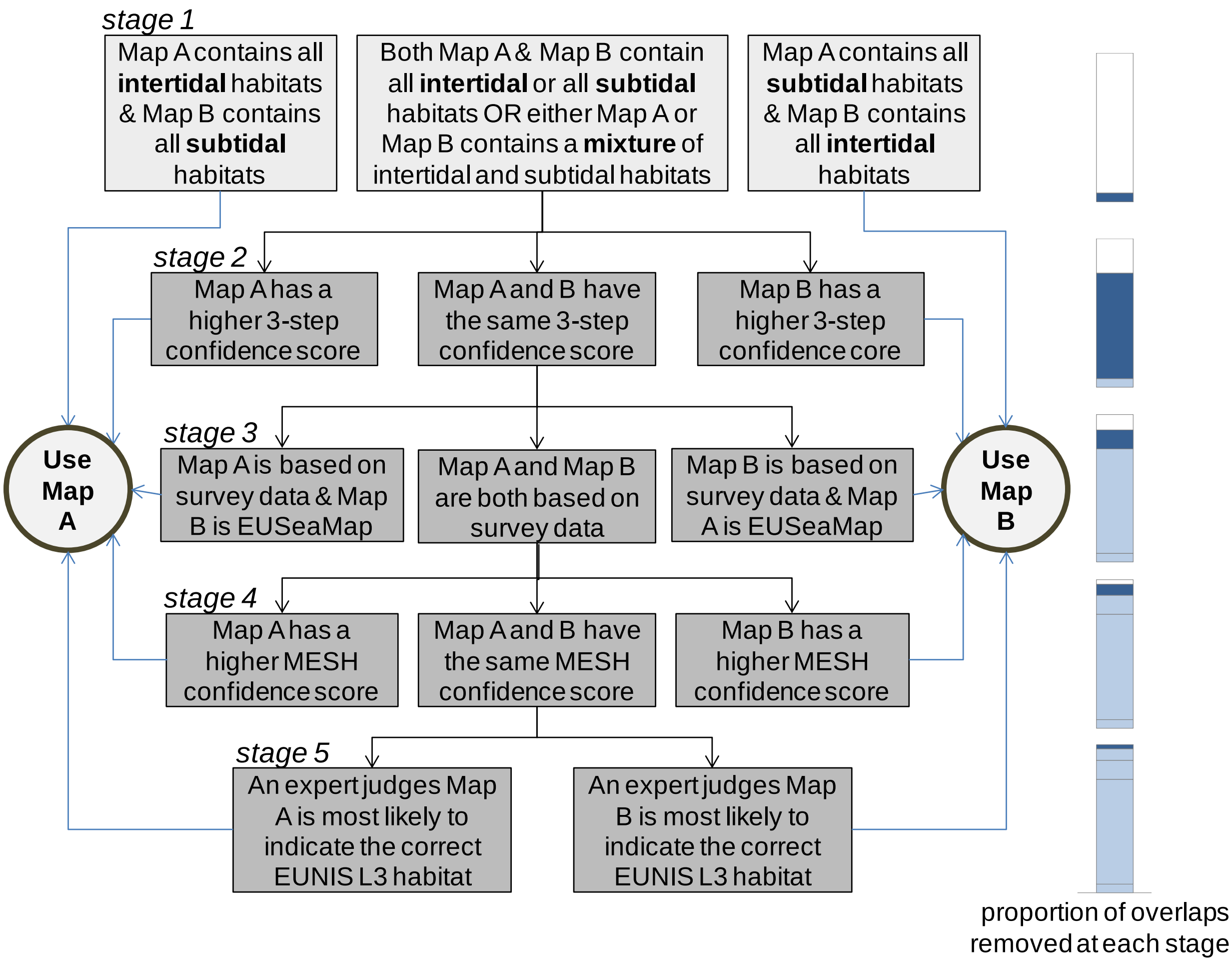
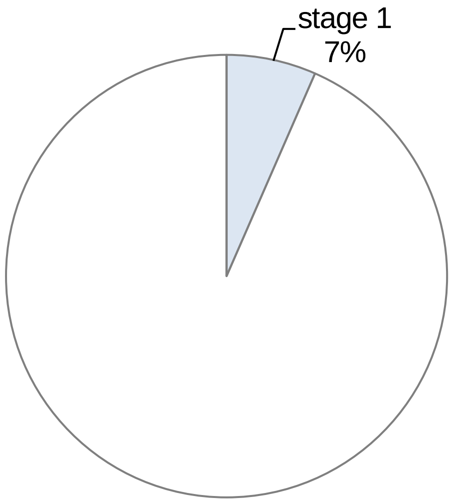


Figure 2: decision tree for the assessment of which of two overlapping habitat maps to use.

Sections 3.1 to 3.5 describe each stage in more detail and summarise the number of overlaps removed at each stage. Note: one overlap refers the entire overlapping area between two mapping studies. EUSeaMap is classed as four maps of equal confidence score in this process (as described in Section 2.3).

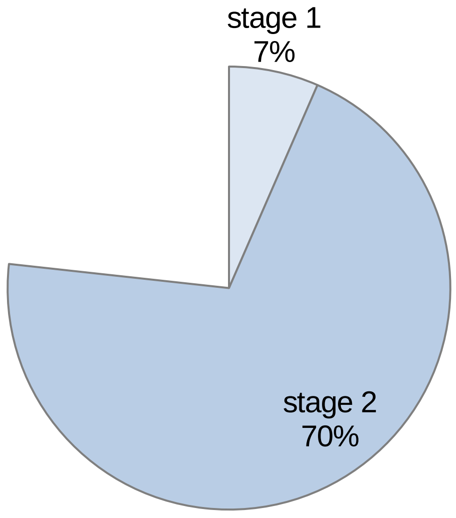
3.1 Stage 1: intertidal or subtidal



65 of 993 overlaps removed in this stage

The first stage removes maps containing all subtidal data that overlap with intertidal survey data – without regard for the confidence scores. This is due to the assumption that the positioning of the intertidal data is likely to be roughly correct because intertidal maps are generally at a more detailed spatial scale than subtidal data.

3.2 Stage 2: three-step confidence assessment

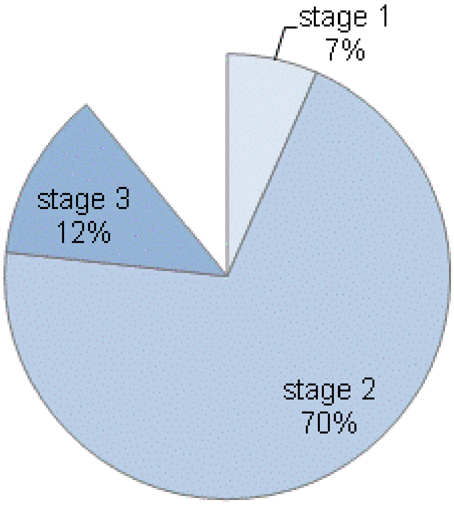


697 of 993 overlaps removed in this stage

77 % of overlaps removed in total

The three-step confidence assessment method described in Section 2 is used in stage 2 of the decision tree and removes the majority of the overlaps by favouring the map with the highest score.

3.3 Stage 3: survey-derived or EUSeaMap

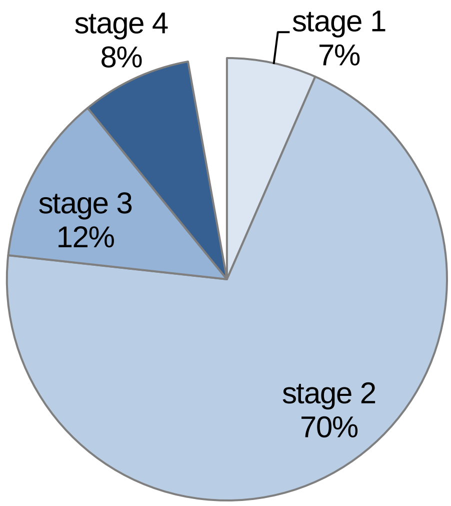


123 of 993 overlaps removed in this stage

89 % of overlaps removed in total

EUSeaMap is assessed using the same confidence assessment method as survey-derived maps (Section 2); however, where a survey-derived map and EUSeaMap coincide and have identical scores, a further criterion must be used to determine which map to use. It was decided that in this situation, the survey-derived map would be used. This is based on the assumptions that the survey-based map (1) used all available data for map interpretation while EUSeaMap was restricted in the data it could use; and (2) is likely to be mapped at the most relevant spatial scale for the habitats in that location while the EUSeaMap resolution is fixed.

3.4 Stage 4: secondary confidence assessment for survey-derived maps



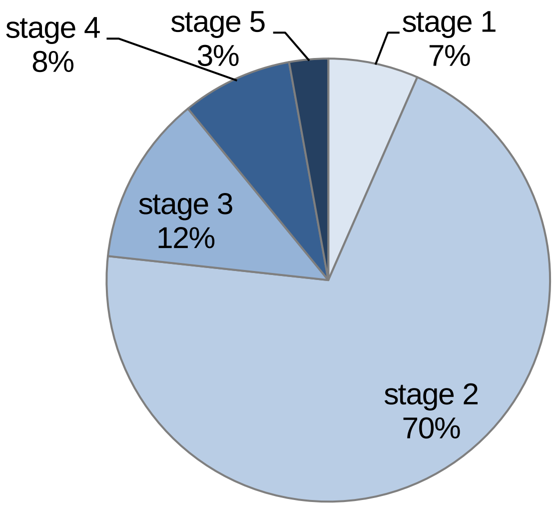
80 of 993 overlaps removed in this stage

97 % of overlaps removed in total

The MESH confidence assessment was the primary tool for deciding which map to use in overlapping areas in the 2011 combined EUNIS level 3 map (described in Section 1.3). For this 2013 version, it was used as a secondary assessment to determine which map to use where two overlapping survey-derived maps have the same score according to the 3-step assessment. The MESH confidence assessment was chosen for this because most of the survey-derived maps also had MESH confidence scores assigned and it provides a more detailed assessment of the quality of a map by including additional factors such as the age of data, the techniques used, positioning method and interpretation technique.

More information on the MESH confidence method is given in Appendix 2 and MESH Project (2008).

3.5 Stage 5: expert judgement and additional information



28 of 993 overlaps removed in this stage

100 % of overlaps removed in total

By stage 5, 97 % of overlaps had been resolved, leaving just 28 pairs of overlapping survey-derived maps with identical confidence scores according to both the three-step assessment and the MESH confidence assessment. Additional information (where available and relevant) and expert judgement were used to decide which map to clip using factors such as vintage, the relative level of spatial detail, whether the polygons were intertidal or subtidal and/or the survey techniques. Data that informed the decisions included bathymetry, mean low water line, light penetration and energy, among others. All cases and the reasons for the final decision were recorded and listed in Appendix 3.

4 Final product

The final product (Figure 3) is a vector feature class GIS layer with an associated attribute table as described in Appendix 4; it is based on the MESH 'translated habitat data exchange format' (Coltman, 2005). There is an accompanying spreadsheet containing metadata on each of 210 the datasets input to the study.

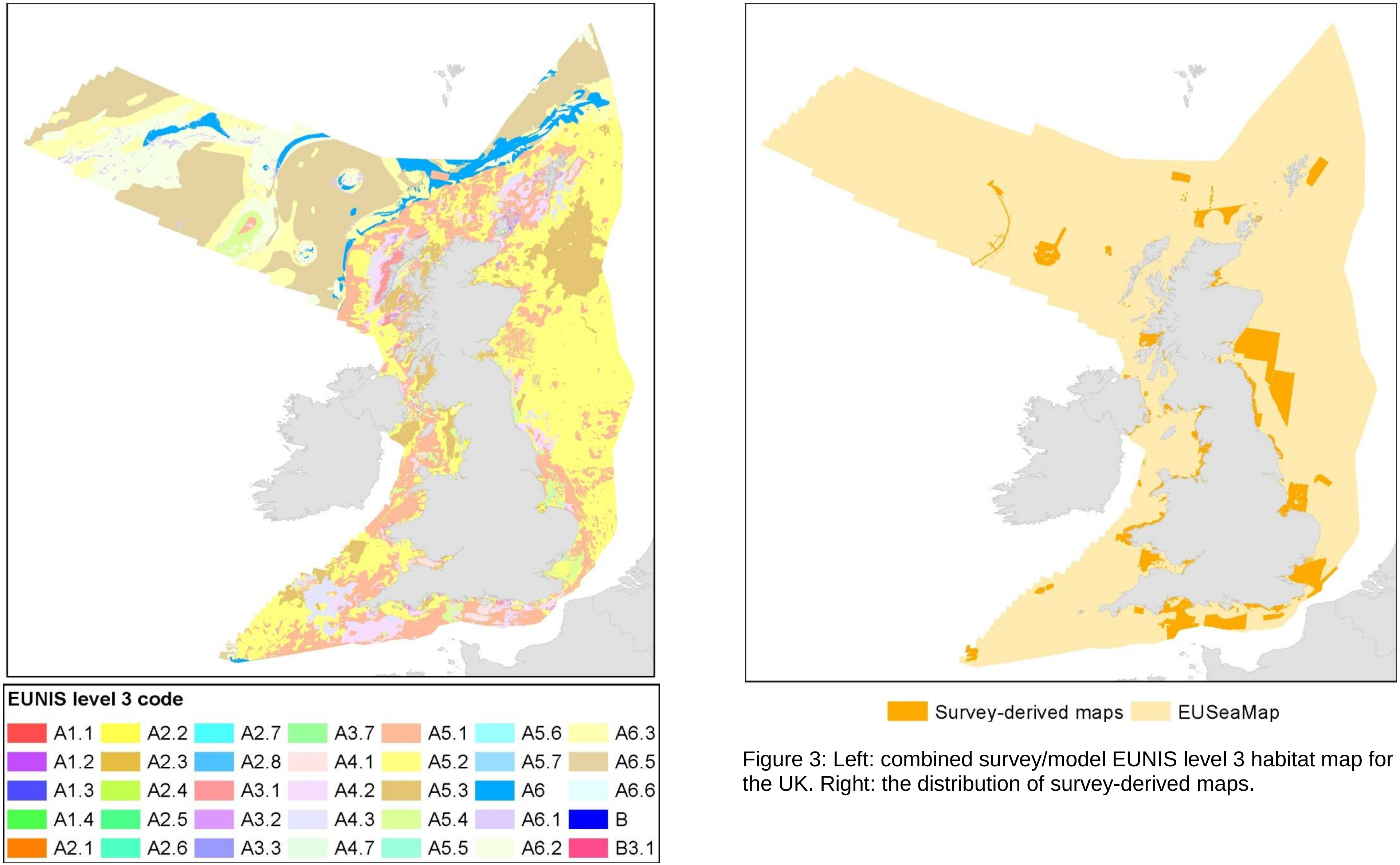


Figure 3: Left: combined survey/model EUNIS level 3 habitat map for the UK. Right: the distribution of survey-derived maps.

5 Evaluation of 2013 approach

5.1 Benefits

The procedure described in Section 3 addresses many of the issues described in Section 1.4:

1. The three-step confidence assessment method has been specifically developed to score a map's ability to map EUNIS level 3 habitats.

2. The three-step confidence assessment method is applied to all survey-derived and broad-scale maps from habitat models, meaning:
    a. The confidence in the final combined map can be described consistently everywhere; and,
    b. Variation in the confidence of the broad-scale map from the EUSeaMap model is considered as well as confidence in the survey-derived maps.

3. The three-step confidence assessment method is based on only three criteria, and is scored out of four, making it simpler to understand.

5.2 Limitations

JNCC want to highlight the many limitations associated with the approach to deriving this product, clearly due to the variety in spatial scales and survey techniques used in the creation of the original habitat maps. These limitations are described in detail in a report written by Cefas and JNCC for the Marine Management Organisation in 2012 (MMO, 2012). JNCC strongly advise this report is read by anyone intending to use our 2013 product. However, users must note that the method used to create our 2013 product uses a revised approach to assessing the confidence and combining maps since the MMO report was written so some sections are no longer be relevant to this 2013 product.

Specific developments that may improve the process in future include:

1. In stage 1 of the decision tree (see Section 3.1) a polygon-level assessment could favour all intertidal data over all subtidal data (as opposed to only whole maps that contain all intertidal data being favoured over whole maps that contain all subtidal data).

2. In this 2013 process, any polygons in survey habitat maps that were only classified as far as EUNIS level 2 were excluded and EUSeaMap was favoured, even if the survey map containing level 2 codes had a higher confidence score. For these cases, polygons from the survey maps classified to level 2 rock (A1, A3 or A4) could be extended to EUNIS level 3 using EUSeaMap energy levels to ensure the best available data being used at every location.

3. The third step of the confidence assessment (Section 2) scores the distinctness of class boundaries. To save time, JNCC used a simple rule to answer the question for all older survey maps: if there are more than two substrate types in a map, then this step scored 0, otherwise it scored 1. Spending time looking at each of the maps and scoring accordingly may lead to an improved product as some substrate types are easier to distinguish than others.

6 References

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Appendix 1: EUNIS level 3 habitats in the UK

EUNIS code	EUNIS name
A1.1	High energy littoral rock
A1.2	Moderate energy littoral rock
A1.3	Low energy littoral rock
A1.4	Features of littoral rock
A2.1	Littoral coarse sediment
A2.2	Littoral sand and muddy sand
A2.3	Littoral mud
A2.4	Littoral mixed sediments
A2.5	Coastal saltmarshes and saline reedbeds
A2.6	Littoral sediments dominated by aquatic angiosperms
A2.7	Littoral biogenic reefs
A2.8	Features of littoral sediment
A3.1	Atlantic and Mediterranean high energy infralittoral rock
A3.2	Atlantic and Mediterranean moderate energy infralittoral rock
A3.3	Atlantic and Mediterranean low energy infralittoral rock
A3.7	Features of infralittoral rock
A4.1	Atlantic and Mediterranean high energy circalittoral rock
A4.2	Atlantic and Mediterranean moderate energy circalittoral rock
A4.3	Atlantic and Mediterranean low energy circalittoral rock
A4.7	Features of circalittoral rock
A5.1	Sublittoral coarse sediment
A5.2	Sublittoral sand
A5.3	Sublittoral mud
A5.4	Sublittoral mixed sediments
A5.5	Sublittoral macrophyte-dominated sediment
A5.6	Sublittoral biogenic reefs
A5.7	Features of sublittoral sediments
A6.1	Deep-sea rock and artificial hard substrata
A6.2	Deep-sea mixed substrata
A6.3	Deep-sea sand
A6.4	Deep-sea muddy sand

EUNIS code	EUNIS name
A6.5	Deep-sea mud
A6.6	Deep-sea bioherms
A6.7	Raised features of the deep-sea bed
A6.8	Deep-sea trenches and canyons, channels, slope failures and slumps on the continental slope
A6.9	Vents, seeps, hypoxic and anoxic habitats of the deep sea
B1.1	Sand beach driftlines
B1.2	Sand beaches above the driftline
B1.3	Shifting coastal dunes
B1.4	Coastal stable dune grassland (grey dunes)
B1.5	Coastal dune heaths
B1.6	Coastal dune scrub
B1.7	Coastal dune woods
B1.8	Moist and wet dune slacks
B1.9	Machair
B2.1	Shingle beach driftlines
B2.2	Unvegetated mobile shingle beaches above the driftline
B2.3	Upper shingle beaches with open vegetation
B2.4	Fixed shingle beaches, with herbaceous vegetation
B2.5	Shingle and gravel beaches with scrub
B2.6	Shingle and gravel beach woodland
B3.1	Supralittoral rock (lichen or splash zone)
B3.2	Unvegetated rock cliffs, ledges, shores and islets
B3.3	Rock cliffs, ledges and shores, with angiosperms
B3.4	Soft sea-cliffs, often vegetated

Appendix 2: MESH Confidence Assessment Scoring System

For an introduction to the MESH confidence assessment, see MESH Project (2008): www.searchmesh.net/Default.aspx?page=1635.

Confidence field	Confidence group	Confidence question	Comments
Remote sensing data collection			
RemoteTechnique	How good is the remote sensing?	Were the techniques used appropriate for the ground type?	An assessment of whether the remote technique(s) used to produce this map were appropriate to the environment they were used to survey. If necessary, adjust your assessment to account for technique(s) which, although appropriate, were used in deep water and consequently have a significantly reduced resolution (i.e size of footprint): 3 = technique(s) highly appropriate 2 = technique(s) moderately appropriate 1 = technique(s) inappropriate
RemoteCoverage	How good is the remote sensing?	Was the ground covered appropriately?	An assessment of the coverage of the remote sensing data including consideration of heterogeneity of the seabed: **Coverage scores – use these to determine coverage then combine with heterogeneity assessment to derive final scores** 3 = good coverage; 100% (or greater) coverage or AGDS track spacing <50m 2 = moderate coverage; swath approx 50% coverage or AGDS track spacing <100m 1 = poor coverage; large gaps between swaths or AGDS track spacing >100m **Final scores** 3 = good coverage **OR** moderate coverage + low heterogeneity 2 = moderate coverage + moderate heterogeneity **OR** poor coverage + low heterogeneity 1 = moderate coverage + high heterogeneity **OR** poor coverage + moderate or high heterogeneity
RemotePositioning	How good is the remote sensing?	How were the positions determined for the remote data?	An indication of the positioning method used for the remote data: 3 = differential GPS 2 = GPS (not differential) or other non-satellite ‘electronic’ navigation system 1 = chart based navigation, or dead-reckoning

RemoteStdsApplied	How good is the remote sensing?	Were standards applied to the collection of the remote data?	An assessment of whether standards have been applied to the collection of the remote data. This field gives an indication of whether some data quality control has been carried out: 3 = remote data collected to approved standards 2 = remote data collected to 'internal' standards 1 = no standards applied to the collection of the remote data
RemoteVintage	How good is the remote sensing?	How recent are the remote data?	An indication of the age of the remote data: 3 = < 5yrs old. 2 = 5 to 10 yrs old. 1 = > 10 years old

Ground-truth data collection

BGTTechnique	How good is the ground-truthing?	Were the techniques used appropriate for the habitats encountered?	An assessment of whether the ground-truthing techniques used to produce this map were appropriate to the environment they were used to survey. Use scores for soft or hard substrata as appropriate to the area surveyed. **Soft substrata predominate (i.e. those having infauna and epifauna)** 3 = infauna AND epifauna sampled AND observed (video/stills, direct human observation) 2= infauna AND epifauna sampled, but NOT observed (video/stills, direct human observation) 1 = infauna OR epifauna sampled, but not both. No observation. **Hard substrata predominate (i.e. those with no infauna)** 3 = sampling included direct human observation (shore survey or diver survey) 2 = sampling included video or stills but NO direct human observation 1 = benthic sampling only (e.g. grabs, trawls)
PGTTechnique	How good is the ground-truthing?	How appropriate were the sampling techniques to determining the geophysical nature of the seabed?	An assessment of whether the combination of geophysical sampling techniques was appropriate to the environment they were used to survey. Use scores for soft or hard substrata as appropriate to the area surveyed. **Soft substrata predominate (gravel, sand, mud)** 3 = full geophysical analysis: granulometry and/or geophysical testing (e.g. penetrometry, shear strength) 2 = sediments described following visual inspection of grab or core samples (e.g. slightly shelly, muddy sand) 1 = sediments described on the basis of remote observation (by camera).

			Hard substrata predominate (rock outcrops, boulders, cobbles) 3 = sampling included in-situ, direct human observation (shore survey or diver survey) 2 = sampling included video or photographic observation, but NO in-situ, direct human observation 1 = samples obtained only by rock dredge (or similar)
GTPositioning	How good is the ground-truthing?	How were the positions determined for the ground-truth data?	An indication of the positioning method used for the ground-truth data: 3 = differential GPS 2 = GPS (not differential) or other non-satellite 'electronic' navigation system 1 = chart based navigation, or dead-reckoning
GTDensity	How good is the ground-truthing?	Was the density of sampling adequate?	An assessment of what proportion of the polygons or classes (groups of polygons with the same 'habitat' attribute) actually contain ground-truth data: 3 = Every class in the map classification was sampled at least 3 times 2 = Every class in the map classification was sampled 1 = Not all classes in the map classification were sampled (some classes have no ground-truth data)
GTStdsApplied	How good is the ground-truthing?	Were standards applied to the collection of the ground-truth data?	An assessment of whether standards have been applied to the collection of the ground-truth data. This field gives an indication of whether some data quality control has been carried out: 3 = ground-truth samples collected to approved standards 2 = ground-truth samples collected to 'internal' standards 1 = no standards applied to the collection of ground-truth samples
GTVintage	How good is the ground-truthing?	How recent are the ground-truth data?	An indication of the age of the ground-truth data: 3 = < 5yrs old 2 = 5 to 10 yrs old 1 = > 10 years old

Data interpretation

GTInterpretation	How good is the interpretation?	How were the ground-truthing data interpreted?	An indication of the confidence in the interpretation of the ground-truthing data. Score a maximum of 1 if physical ground-truth data but no biological ground-truth data were collected: 3 = Evidence of expert interpretation; full descriptions and taxon list provided for each habitat class 2 = Evidence of expert interpretation, but no detailed description or taxon list supplied for each habitat class 1 = No evidence of expert interpretation; limited descriptions available

RemoteInterpretation	How good is the interpretation?	Were the remote data appropriately interpreted?	An indication of the confidence in the interpretation of the remotely sensed data: 3 = Appropriate technique used and documentation provided 2 = Appropriate technique used but no documentation provided 1 = Inappropriate technique used Note that interpretation techniques can range from 'by eye' digitising of side scan by experts to statistical classification techniques.
DetailLevel	How good is the interpretation?	What level of information is contained?	The level of detail to which the 'habitat' classes in the map have been classified: 3 = Classes defined on the basis of detailed biological analysis 2 = Classes defined on the basis of major characterising species or lifeforms 1 = Classes defined on the basis of physical information, or broad biological zones
MapAccuracy	How good is the interpretation?	How accurate is the map at representing reality?	A test of the accuracy of the map: 3 = high accuracy, proven by external accuracy assessment 2 = high accuracy, proven by internal accuracy assessment 1 = low accuracy, proved by either external or internal assessment OR no accuracy assessment made

Note on Remote Coverage:

The score for 'RemoteCoverage' should take account of both coverage **and** heterogeneity and this can be simply achieved in a *coverage x heterogeneity* matrix, as illustrated below:

		Heterogeneity		
		Low	Moderate	High
Coverage	Poor	2	1	1
	Moderate	3	2	1
	Good	3	3	3

Appendix 3: Actions taken for overlapping studies with the same confidence scores

Table 3: A list of overlapping mapping studies with identical scores for both the three-step confidence assessment and the MESH confidence assessment. These overlaps were resolved by expert judgement in stage 5 (see Section 3.5). The globally unique identifier (GUI) of the maps chosen to 'win' in each situation is listed in column 1 ('GUI of chosen map'). The reason for each judgement is given in column 5 ('Justification'). A hyphen ('-') in columns 3 and 4 ('3-step score' and 'MESH score') indicates that a confidence score has not been calculated for either of the maps, usually due to the survey report and/or metadata not being available.

GUI of chosen map	GUI of loosing map	3-step score	MESH score	Justification
GB000225	GB000226	0	24	GB000225 contains all intertidal data while GB000226 contains a mixture of subtidal and intertidal data; therefore GB000225 was selected.
GB000228	GB000229	2	74	At the polygon level, GB000228's intertidal polygons overlap GB000229's subtidal polygons so following stage 1 in Figure 2, GB000228 was selected.
GB000232	GB000235	-	-	The two maps have a negligible overlapping area – slivers on the order of mm wide, therefore the choice is insignificant. GB000232 was chosen because it is more spatially detailed.
GB000233	GB001069	-	-	The two maps have a negligible overlapping area – slivers on the order of mm wide, therefore the choice is insignificant. No clear factors to make a decision so selected GB000233 to match the decision of a previous contract (Frost, 2010).
GB000233	GB001070	-	-	The two maps have a negligible overlapping area – slivers on the order of mm wide, therefore the choice is insignificant. No clear factors to make a decision so selected GB000233 to match the decision of a previous contract (Frost, 2010).
GB000239	GB000240	2	71	Both maps are from same original data, but GB000239 was chosen because it is more spatially detailed
GB000245	GB000249	-	-	The two maps have a negligible overlapping area – slivers on the order of mm wide, therefore the choice is insignificant.
GB000247	GB001070	-	-	The two maps have a negligible overlapping area – slivers on the order of mm wide, therefore the choice is insignificant. No clear factors to make a decision so selected GB000247 to match the decision of a previous contract (Frost, 2010).
GB000372	GB000282	-	-	Both maps have some projection issues but GB000372 seems less distorted.
GB000287	GB000374	1	42	The two maps have a negligible overlapping area – slivers on the order of mm wide, therefore the choice is insignificant. GB000287 was chosen because it's more spatially detailed.
GB000293	GB000288	1	42	The two maps have a negligible overlapping area – slivers on the order of mm wide, therefore the choice is insignificant. GB000293 was chosen because it's more spatially detailed.
GB000292	GB000289	1	42	At the polygon level, GB000292's intertidal polygons overlap GB000289's subtidal polygons so following stage 1 in Figure 2, GB000292 was selected.

GUI of chosen map	GUI of loosing map	3-step score	MESH score	Justification
GB000293	GB000290	1	42	The two maps have a negligible overlapping area – slivers on the order of mm wide, therefore the choice is insignificant. GB000293 chosen because it's more spatially detailed.
GB000291	GB000646	1	42	The two maps have a negligible overlapping area – slivers on the order of mm wide, therefore the choice is insignificant. GB000291 chosen because it's more spatially detailed.
GB000292	GB000376	1	42	At the polygon level, GB000292's intertidal polygons more often overlap GB000376's subtidal polygons so following stage 1 in Figure 2, GB000292 was selected.
GB000318	GB000317	-	-	Both maps agree on the habitat but GB000318 was chosen because GB000317 contains data from the 1870s.
GB000326	GB001070	-	-	The two maps have a negligible overlapping area – slivers on the order of mm wide, therefore the choice is insignificant. No clear factors to make a decision so selected GB000326 to match the decision of a previous contract (Frost, 2010).
GB000331	GB001069	-	-	The two maps have a negligible overlapping area – slivers on the order of mm wide, therefore the choice is insignificant. No clear factors to make a decision so selected GB000331 to match the decision of a previous contract (Frost, 2010).
GB000331	GB001070	-	-	The two maps have a negligible overlapping area – slivers on the order of mm wide, therefore the choice is insignificant. No clear factors to make a decision so selected GB000331 to match the decision of a previous contract (Frost, 2010).
GB000332	GB000335	-	-	The two maps have a negligible overlapping area – slivers on the order of mm wide, therefore the choice is insignificant.
GB000923	GB000335	-	-	Both maps agree on the habitat way but GB000923 was chosen because it is more recent.
GB000979	GB000978	-	-	GB000978 sometimes goes above MHW, which is incorrect. Therefore we have less confidence in its spatial accuracy.
GB100002	GB100003	2	62	Maps contain exactly the same data, so the choice was inconsequential.
GB100003	GB100004	2	62	Maps contain exactly the same data, so the choice was inconsequential.
GB100018	GB100020	2	64	Both maps agree on the habitat but GB100018 was chosen because it is more spatially detailed.
GB100031	GB100083	2	51	Both cite the same report as a reference and both contain the same metadata but the data disagree. The report contains no maps. GB100031 looks more likely because it has infralittoral in shallow waters whereas GB100083 has circalittoral.

Appendix 4: Format for attribute table

Table 4: The attribute table format is equivalent to the MESH Translated Habitat Data Exchange Format (Coltman, 2005), with the addition of three fields: HAB_LEVEL3, SOURCE and CONFIDENCE.

Field	Description	Input
POLYGON	Identification number for each polygon	e.g. 103
GUI	Globally unique identifier for each original dataset; use this to link to the accompanying metadata spreadsheet to get more information about the data.	e.g. “GB001037”
ORIG_HAB	Original habitat description	e.g. “Circalittoral rock with faunal turf”
HAB_TYPE	Habitat type according to EUNIS habitat classification	e.g. “A4.31”
VERSION	Version of EUNIS used in HAB_TYPE field, if relevant	e.g. “EUNIS version 2007-11”
DET_MTHD	Method of determining EUNIS habitat in HAB_TYPE field, if relevant	e.g. “redetermination by class”
DET_NAME	Name of determiner	e.g. “Joe Bloggs”
DET_DATE	Date of determination of EUNIS habitat in HAB_TYPE field, if relevant	e.g. “31/12/2009”
TRAN_COM	Comment on the translation of original habitat (ORIG_HAB) to EUNIS habitat in HAB_TYPE field, if relevant	Free text
T_RELATE	Relationship between original habitat (ORIG_HAB) and EUNIS habitat (HAB_TYPE)	=/≈/</>/#/S (see JNCC, 2010 for explanation)
VAL_COMM	Validation comments	Free text
EUNIS_L3	Habitat type at level 3 of EUNIS	e.g. “A4.3”

Appendix 5: Version Control

BUILD STATUS:

Version	Date	Author	Reason/Comments
0.1	28/10/13	Helen Ellwood	To describe the process used to create the 2013 combined EUNIS level 3 habitat map.
0.2	26/11/13	Helen Ellwood	Edits made according to comments by Natalie Askew.
0.3	28/01/14	Helen Ellwood	Clarification about the meaning of confidence
0.4	05/02/14	Helen Ellwood	Edits made according to comments by Natural England
1.0	11/03/14	Helen Ellwood	Finalised

DISTRIBUTION:

Copy	Version	Issue Date	Issued To
Electronic	0.1	28/10/13	Internal – Natalie Askew and Jon Davies
Electronic	0.2	08/01/14	Internal – Natalie Askew
Electronic	0.3	28/01/14	Inter-agency mapping group
Electronic	0.4	11/03/14	Internal – Natalie Askew
Electronic	1.0	11/03/14	Public - online