UKSeaMap 2010
Technical Report 7

External Review of Confidence Assessment Methods

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1 Introduction

When the UKSeaMap 2010 report was in a late draft stage, a report was commissioned by JNCC to externally review the MESH (MESH, 2008) and UKSeaMap 2010 methods for assessing confidence in habitat maps. This work was undertaken by Marine Ecological Surveys Limited (MES), who produced a report entitled “Review of Confidence Assessment Methods for use in the Marine Biodiversity Surveillance and Monitoring Programme” in March 2011.

This technical report contains extracts from the MES report that relate to UKSeaMap 2010. These are, in full and word-for-word, Sections 4 and 6 from the original report (Sections 2 and 3 in this report). The only differences between the extracts here and the sections in the original report are the formatting and heading, table and figure numbers.

1.1 Changes made since the confidence review

Section 4.2 in the main UKSeaMap report describes the method used to combine confidence layers for the model input layers to produce the final confidence map. The approach was modified partly as a result of this review and therefore the approach referred to in this technical report is no longer the approach used.

Where a recommendation refers to changes in the main or technical reports for UKSeaMap 2010, it can be assumed that these have also been addressed and therefore are no longer relevant. The main recommendations still to be addressed are those labelled as “R&D” in Table 1. These will be considered for any future modelling work undertaken.

2 Review of UKSeaMap 2010 Confidence Assessment

2.1 UKSeaMap 2010 confidence overview

The way in which confidence has been measured for the predicted UKSeaMap 2010 EUNIS map is fundamentally different to survey based MESH EUNIS map for the majority of the assessment. This section details the UKSeaMap 2010 assessment; following this, some alternate methods are explored in Section 3.

UKSeaMap 2010 provides a confidence assessment to each of the contributing layers of (a) biological zone, (b) tidal energy at the seabed, (c) wave energy at the seabed and (d) seabed substrate. The biological zone is created by combining layers that define the limit of the photic layer (created from bathymetry and light attenuation), limit of wave disturbance (created from bathymetry and wave height) and deep-sea zones delineated using bathymetry alone. Each of these contributing layers has an individual confidence assessment to inform the biological zone confidence. A diagrammatical summary of the process is shown in Figure 1; whilst the individual confidence layers are shown in Figure 2 to Figure 5; and final (combined) confidence score map is shown in Figure 6.

This review first considers the individual elements contributing to the final confidence layer; then the combination method used to compile the final confidence map.

2.2 Individual components of the UKSeaMap confidence assessment

Overview of UKSeaMap Components

Any assessment of the individual confidence layers necessitates an in-depth examination of the finer details of compiling the predicted environmental layers from which the confidence is derived. This allows for a more complete appreciation of the final confidence map. This is especially important to help inform how to combine UKSeaMap 2010 with the MESH map for the most accurate EUNIS map.

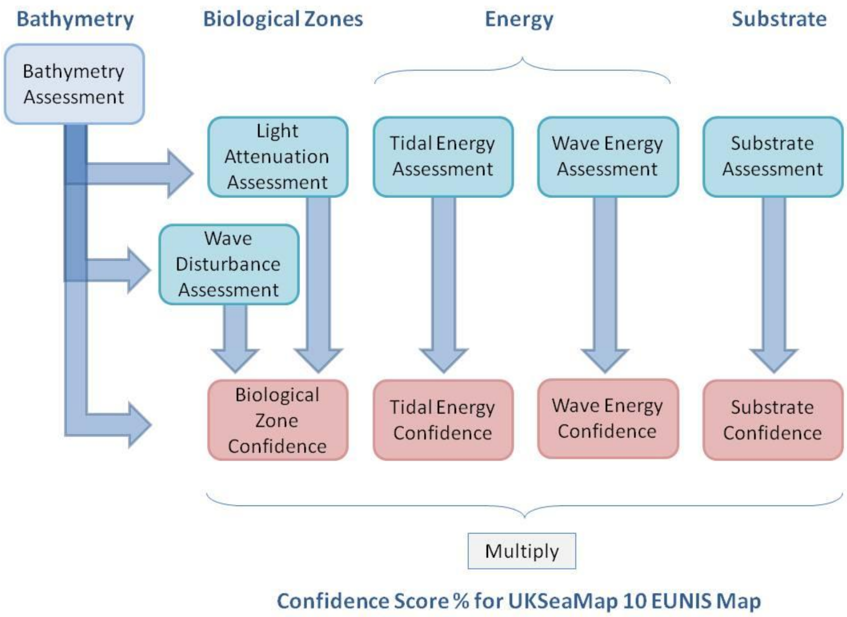

Figure 1: Diagram showing overarching UKSeaMap 2010 confidence assessment method for each contributing parameter. Each of these is broken down further in following diagrams and summaries.

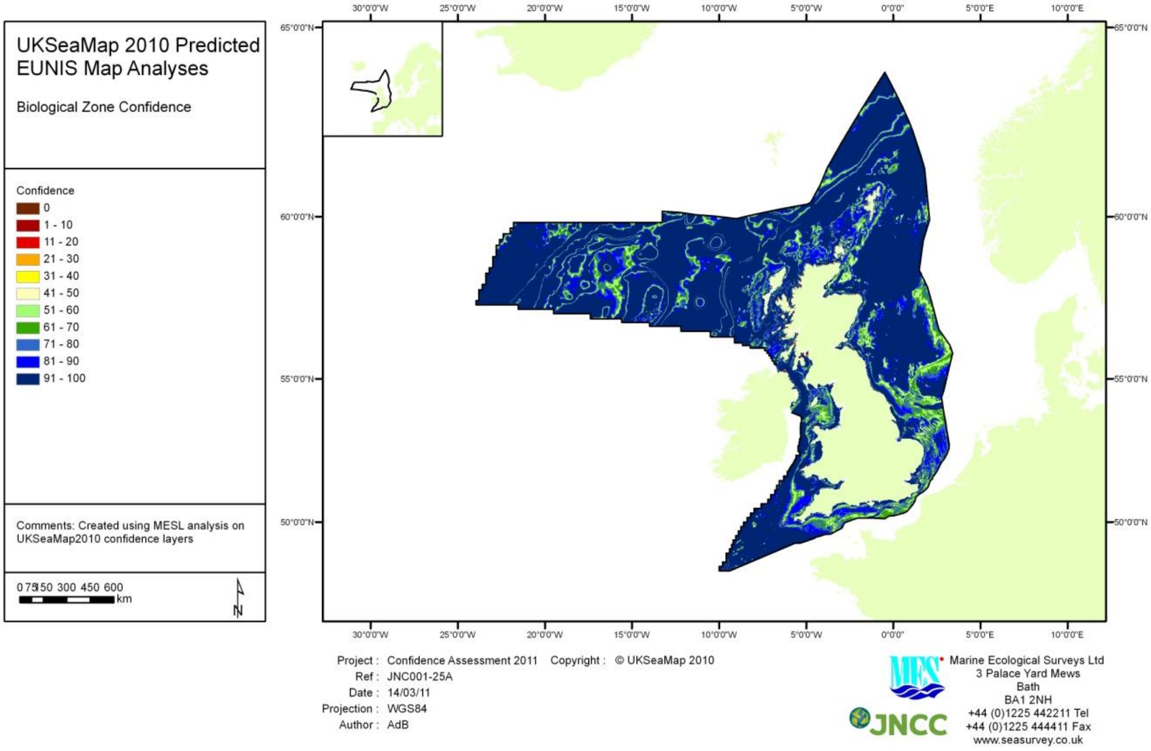

Figure 2: Map showing UKSeaMap 2010 Seabed Habitat Map Confidence Assessment for Biological Zone

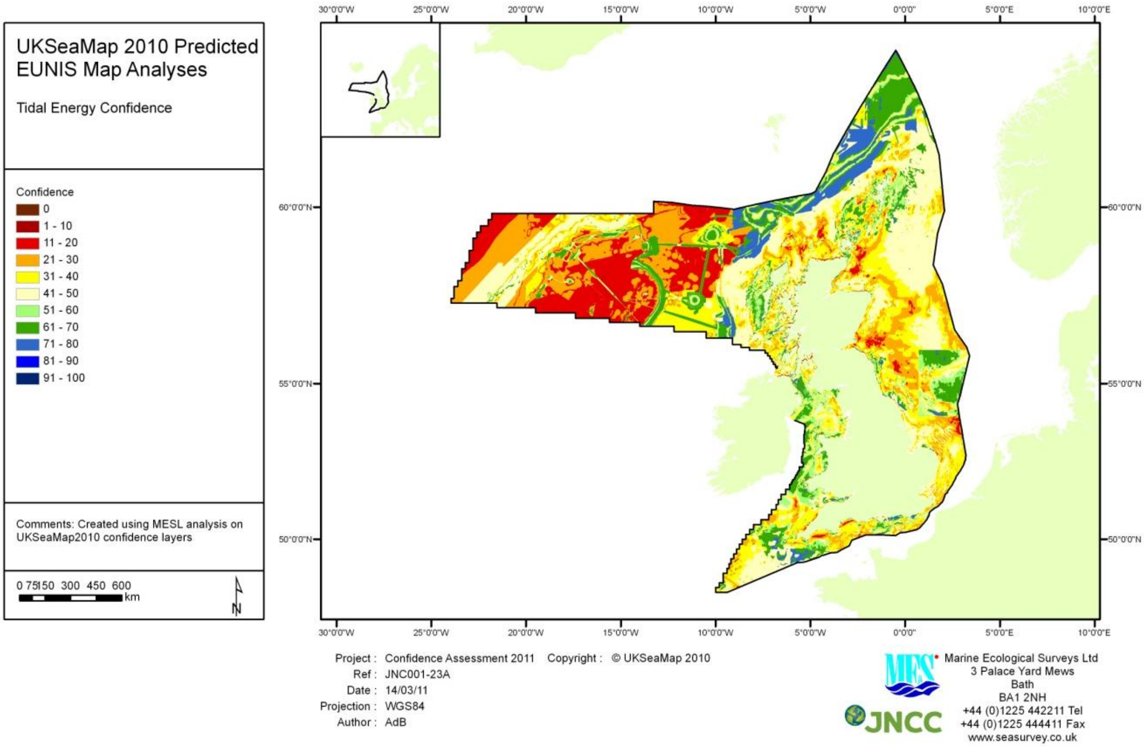

Figure 3: Map showing UKSeaMap 2010 Seabed Habitat Map Confidence Assessment for Tidal Energy at the Seabed

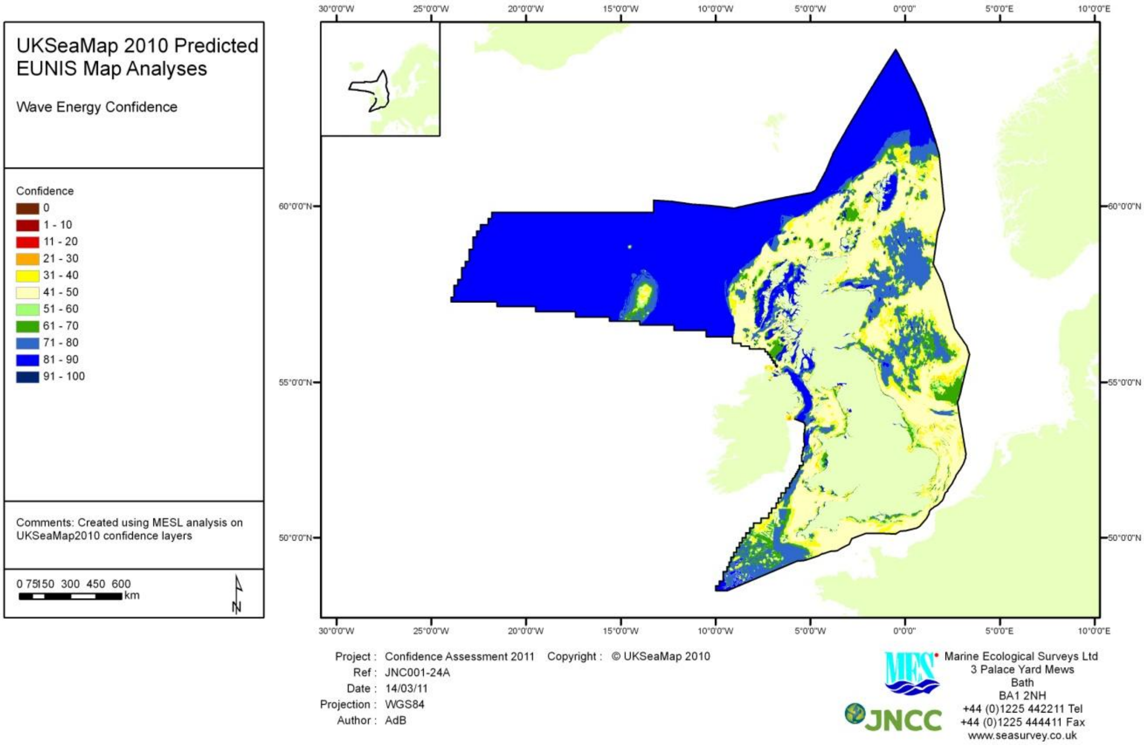

Figure 4: Map showing UKSeaMap 2010 Seabed Habitat Map Confidence Assessment for Wave Energy at the Seabed

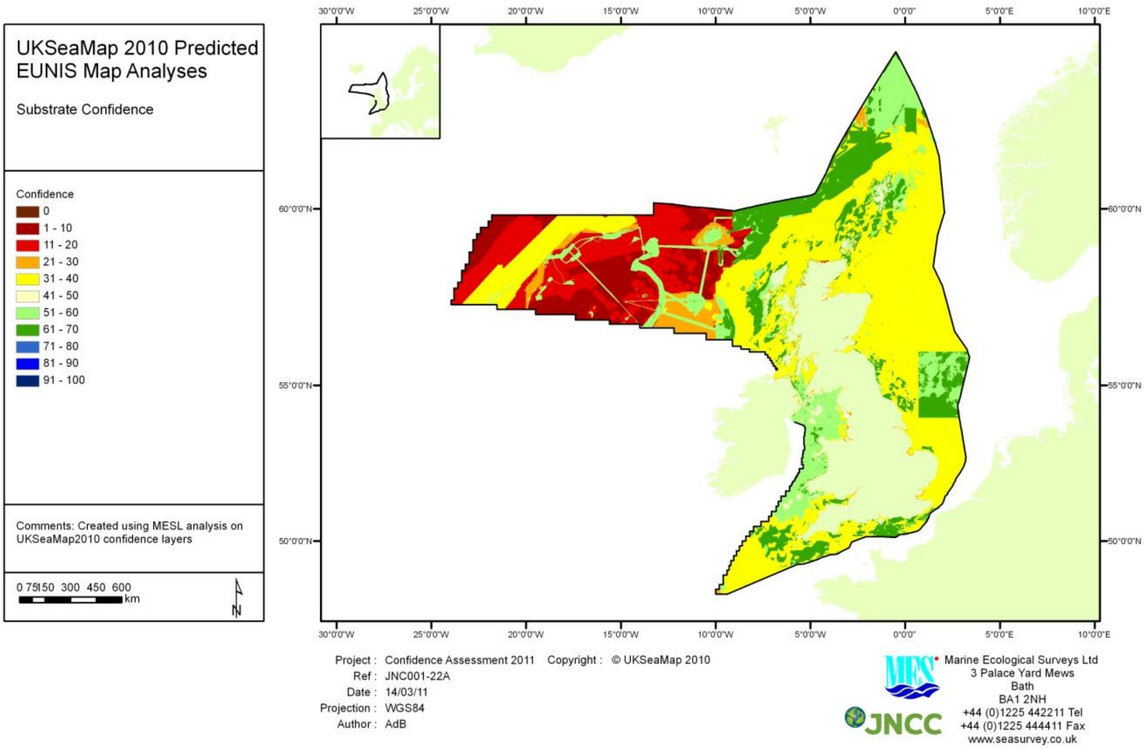

Figure 5: Map showing UKSeaMap 2010 Seabed Habitat Map Confidence Assessment for Substrate

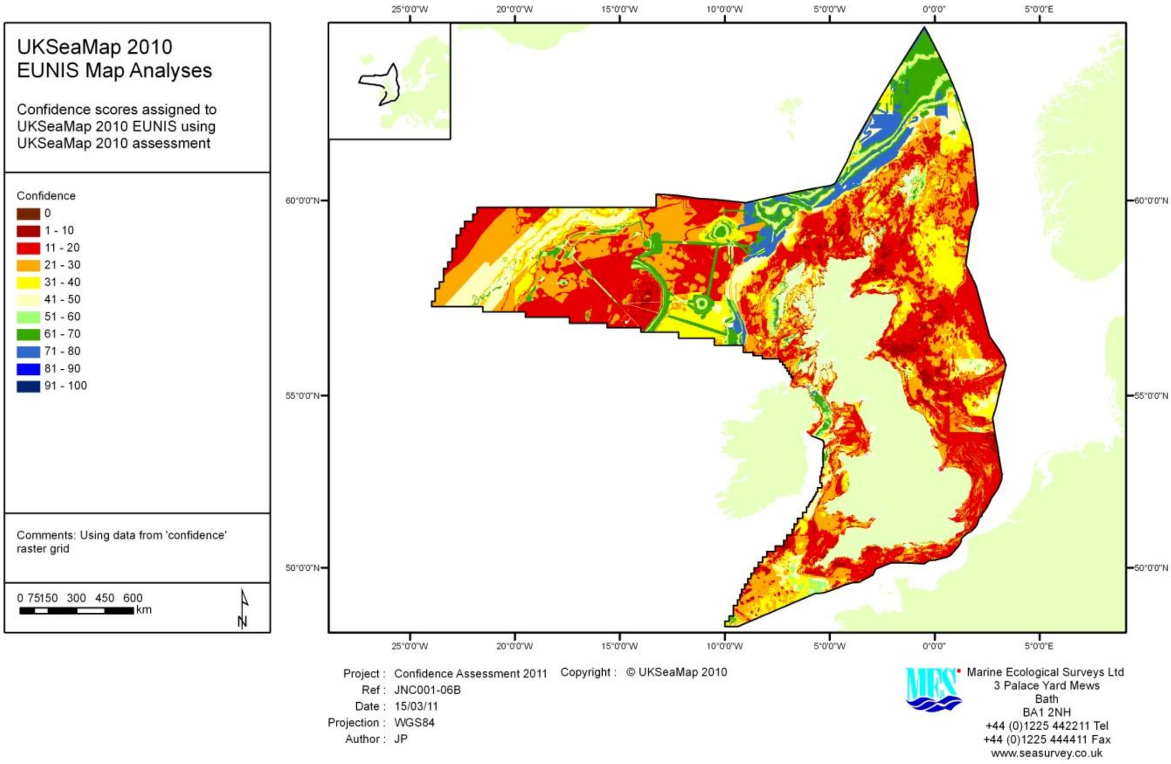

Figure 6: Map showing UKSeaMap 2010 Seabed Habitat Map Confidence Assessment

Detailed Review of UKSeaMap Components

A detailed critique of the individual parameters' confidence assessment, provided as part of this review, is shown in subsequent pages (7-14), and summarised in Table 1. This has been informed by the UKSeaMap 2010 technical reports predominantly, in particular: UKSeaMap 2010 Report No 11 Task 1C 'Assessing the confidence of broadscale classification maps' (Frost & Swift, 2010) and associated technical reports Bathymetry, Light, Substrate, Seabed Energy; BGS report CR/9/168 'Creating and assessing a sediment data layer for UKSeaMap 2010' (Cooper *et al*, 2010); and JNCC Report No 446 'UKSeaMap 2010: Predictive mapping of seabed habitats in UK waters'.

The review includes general comments followed by specific recommendations shown as bullet points at the end of each parameter's critique.

Confidence Parameter:	Map:	Assessment
Bathymetry	UKSM10	Input Data
Input Data	Sea Zone UK bathymetry 'coastal' DEM	
Partial coverage of UK, 30m resolution. Data provided already processed to a certain level, whereby depth 'measurement errors' were negligible for the modern survey techniques, seems true. SeaZone grid produced by triangulation with linear interpolation, with breaklines and contour analysis. Smoothed to a 300m resolution (by ABPMer for the MB0102 layer)		
Input Data	GEBCO Global Bathymetry Jan 2009	

Resolved on a 30” (0.76m) grid, ~900m. Only ship soundings proven to be reliable, as shown from comparison with SeaZone data Water depths have been interpolated for 75% of the project area based on ship soundings using guided gravity data by the GEBCO project group. The ship soundings are used to map the remaining 25% of the area. The GEBCO bathymetry was also then interpolated to a 300m resolution grid to merge with the resampled Sea Zone grid. Depths could have been interpolated to inform SeaZone / GEBCO depth comparison but it is understood that this would require a high computational load which was not available at the time.
Recommendations
◆ Consider further investigation into using date of data as in MESH. Whilst we consider this of lower weighting in MESH, if included in one habitat map should be in both. It is reported that data <100m depth is likely to be modern due to high coastal use. This infers that areas >100m could be assigned less confidence if considering ‘vintage’.

Confidence Parameter:	Map:	Assessment
Bathymetry	UKSM10	Confidence
Confidence Type	Sea Zone : Probability, deviation of point values from grid cell value	
Examines variation in SeaZone point depths across 300m SeaZone interpolated cells. Calculation of standard deviations of contributing SeaZone depths per cell and the average of these gives confidence for these areas		
Confidence Type	SeaZone + GEBCO	
SeaZone + GEBCO comparison in SeaZone areas to apply findings to non SeaZone areas according to depth category. Mean depth of 9*300m SeaZone interpolated model cells compared to ~900m GEBCO cell. However as an alternative, we note the SeaZone could have been interpolated from its original 30m resolution data to compile data to match the GEBCO cells. This would be more accurate but may have been too demanding on computational load. Differentiation made between GEBCO data from ship sounding cells versus interpolation. Confidence assigned from the probability density functions that are derived cell by cell from the standard deviations. Report states pattern of standard deviations appear depth related and could equally be due to reduced density of soundings in greater depths. We note that there are five instances where the standard deviations derived from GEBCO depth soundings (SID-1) are greater than those from GEBCO interpolation (SID-0, Table A2). We note that a query made during report to Scripps is not yet resolved regarding appropriate number of standard deviations which impacts method 1) standard deviations used in SeaZone areas and 2) max standard deviations Table 2 >250m		
Recommendations		
◆ Define better how SeaZone data is interpolated to 900m resolution ◆ Consider further investigation into using SeaZone depths with GEBCO values before averaging to get range of standard deviations per GEBCO cell, this information is lost ◆ Define better how standard deviations are allocated (Section A2) when looking at		

SeaZone + GEBCO. Implies that for non SeaZone areas, depths <250m use standard deviations for both of soundings and interpolated GEBCO areas; and for depths >250m, the maximum standard deviation of the soundings and interpolated GEBCO areas is used. We will assume this interpretation.

- Define better why 250m depth is used as a division between confidence methods. Would also be useful to define 250m in the categories in Figure A10.
- Define better Figure A11 which marks <0.1 category as grey as well as areas not included in figure so misleading, e.g. in left figure only shows categories for 200<depth<100m yet <200m is grey.
- Define better spatial differences in confidence method using a map, i.e. a) SeaZone, b) SeaZone + GEBCO <250m, and c) SeaZone + GEBCO >250m

Confidence Parameter:	Map:	Assessment
Photic Depth	UKSM10	Input Data
Input Data	MODIS and SeaWifs remote sensing	

Remote sensing MODIS Aqua to provide light attenuation layer at z_1% (although results for $z_{2.36}$% also provided). SeaWiFS data used to inform algorithms only.

MODIS Aqua 4km resolution for period 2003-8. (SeaWiFS 9km resolution – used indirectly to derive formulae)

Algorithm created by NASA applied and further developed for z_1%. Whilst the NASA algorithm in Equation (3), Section B1 is globally applicable, it is important to note that it is accepted that tuned algorithms can be developed in local areas to provide more accurate local signatures (pers. comms. Samanther Lavender, ARGANS), for example the Environment Agency modified chlorophyll algorithm (Chambers et al, 2000). Equation (3) is derived from ground truthing stations across the world but not within the UK seas, as shown in Figure 7. However recent developments may allow for a better assessment by local tuning of algorithms with in-situ data. From pers comm Dr Lavender (ARGANS):

"There are European in-situ datasets including the European Space Agency (ESA) MERMAID database (http://hermes.acri.fr/mermaid/home/home.php) and also data is accessible via the British Oceanographic Data Centre (BODC). However, these are primarily designed for scientific users. NASA have started an activity called the Generalised Inherent Optical Property model (GIOP, http://oceancolor.gsfc.nasa.gov/WIKI/GIOP.html) where users can use freely available software to create specific products. Within Europe, ESA have funded the development of the BEAM software (http://www.brockmann-consult.de/cms/web/beam/) including a Case 2 Regional Processor (a neural network approach) and also ODESA (http://earth.eo.esa.int/odesa/). The CoastColour project (http://www.coastcolour.org/) recently started and is undertaking specialised processing / algorithm development for several coastal regions around the world including the UK."

Recommendations

- Define better the algorithm background to show it is based on a global set of data and is not locally tuned.
- Consider further investigation into light attenuation algorithm relevance for UK waters, either by locally tuning or using existing tuned algorithms. We recognise that it would be a significant undertaking to update the light attenuation algorithm with UK ground truthing but it could be reviewed what studies have already been carried out at a regional level. We also note that there is then an issue in how to combine

different areas with different local algorithms, introducing ‘fuzzy’ boundaries.

- Define better the website links as does not allow access to the data. Alternative links have been provided during this review (Richard Swift, pers. comm.), for example: http://oceancolor.gsfc.nasa.gov/cgi/l3 and the UKSeaMap 2010 report should be updated accordingly

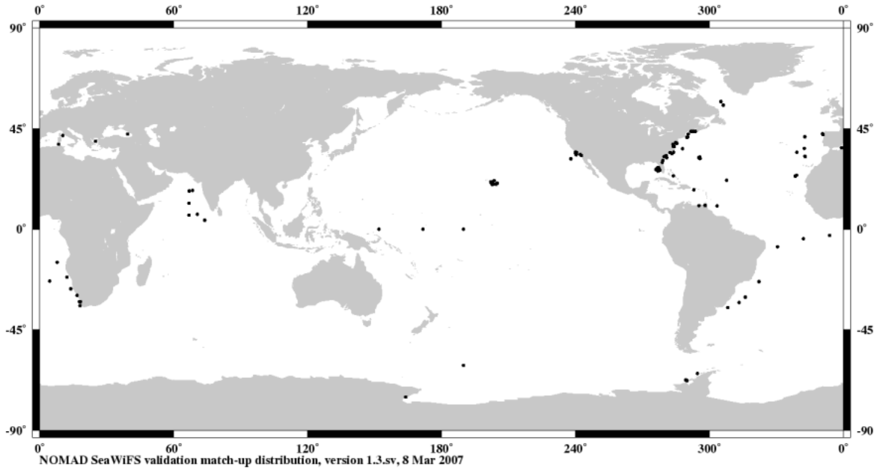

Figure 7: Map showing location of ground truthing points used to test NASA algorithm within UKSeaMap confidence assessment, as referenced in the critique on Photic Depth. Figure obtained from http://seabass.gsfc.nasa.gov/seabass/data/nomad_seabass_v1_seawifs_map.png, copyright NASA

Confidence Parameter:	Map:	Assessment
Photic Depth	UKSM10	Confidence
Confidence Type	Probability, deviation of point values from predicted value	

Derivation of equations based on equal interval bins of NASA data. Scatter of NASA real data provided from NASA predicted K490. Scatter split into K490 bins show normal distribution of difference between values and predicted. Because of normal distribution, a probability equation is applied to each bin. But as probability density function of z_1% is not normally distributed at different K490 values, integration equation is applied to derive probability. Applies confidence of bathymetry layer to final output and combines together by interpolating MODIS to 300m bathymetry grid.

Recommendations

Primary observation is that probability / confidence assumes that the further away from the predicted value, the lower the probability, even though occurrences like this are known, there are just less of them. In one sense this implies the confidence result is ok in that it gives the likelihood of a value at such a standard deviation. But not confidence in the sense of MESH.

- Consider further investigation into algorithm that confidence is based on. Trend of data (predicted K490) shown in Figure B1 and replicated with annotations here in Figure 8 is shown as linear regression but data shows line should be curved (polynomial) or split into two sections above value Lw490/Lw555 = ~1. This would improve prediction at the higher end. However it is recognised that linear regression is standard for this type of ocean colour processing.

◆ Consider further investigation into bin values. In Figure B2, it is noted that K490 is the mid-range value of each bin. This is not true as shown in Figure B1 the predicted value at the higher end of K490 is not within the range of the actual data points plotted. This affects the confidence - as shown in Figure B2 the standard deviation increases with K490.

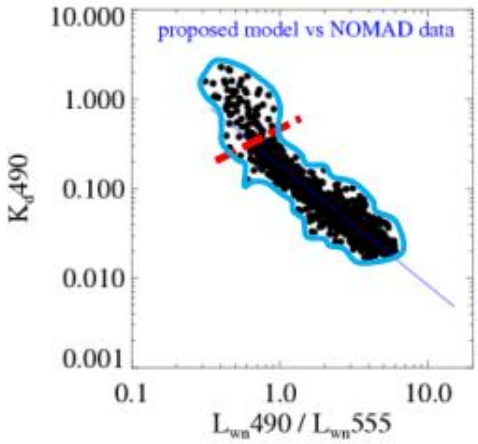

Figure 8: NASA's NOMAD ground truthing data used to verify light attenuation algorithm, annotated to show division where relationship becomes non-linear (red dashed line); and envelope of ground truthing points (blue line). Source: http://oceancolor.gsfc.nasa.gov/REPROCESSING/SeaWiFS/R5.1/k490_update.html

Confidence Parameter:	Map:	Assessment
Wave Disturbance	UKSM10	Input Data
Input Data	ProWAM wave model (POL) wave periods	
2000 – 2004 period inclusive, 12km resolution. Highest waves used for confidence. Interpolated to 300m model grid		
Input Data	Wave periods from CEFAS wave measurement database	
Recorded wave period at 93 post-recovery locations and 38 telemetry sites = 131 total (CEFAS), but only 47 are 2000 – 2004 for comparison to ProWAM. No comparisons have been made between coastal and offshore locations and these may differ. We have reviewed differences and have found only one offshore dataset to be poorly correlated (North Sea A1221), the only post recovery site. So this seems fair not to consider inshore / offshore differences. Filtered to remove low amplitude-long period swell waves and unrealistically steep waves, justified by unpublished findings. Removed wave heights <1.5m for 10 records, as these have greater scatter when relating wave height to period, justified because seabed generally effected by large waves		
Recommendations		
◆ Consider further investigation into the confidence of offshore areas. Figure C2 shows location of the 47 wave stations, with coverage offshore in the Channel and west and north of Scotland is absent so comments re spatial differences are limited		

to North Sea, Outer Bristol Channel and Irish Sea. ◆ Consider obtaining a specialist peer review of data processing method as uses unpublished methods.

Confidence Parameter:	Map:	Assessment
Wave Disturbance	UKSM10	Confidence
Confidence Type	Probability, deviation of point values from predicted value	
Model and measurements best fit for telemetric data and time series of period good fit. Field (post recovery?) and predicted wave period close to normal distributions, model underestimates field values period small amount, perhaps due to instruments / technology vintage. Real datasets can have a more volatile second spectral moment (f^2), implying wave period calculated can be unreliable so a bad fit does not necessarily mean a bad model prediction and could be vice versa. Wave height therefore closer match from model to field data. Also, as distribution of post recovery of some locations fit well with model, assumed those that do not to be ignored and result of measurements Level of agreement between proWAM and telemetry records better than the post-recovery data. Mean and standard deviation plotted of differences between the predictions of wave and point data lead to omission of outlier points / stations leaving 27. Average of mean of differences taken, though is step like (cumulative plots), -0.21s. Standard deviation taken from differentiation as curve like (cumulative plot), centre of distribution taken, 0.52s Normal distribution used to give probability density function based on above figures using: if water depth < 0.5*wavelength, seabed disturbed. Wavelength calculated from period using wave dispersion theory		
Recommendations		
◆ Define better with regards to term 'field data' which seems to be used for post recovery site data collection – better to use 'post recovery' as referenced at start, to help reader follow process applied ◆ Consider further investigation into which of these measurement locations were used to validate the model by POL originally, those used we would expect good match anyway and is therefore circular use of data and shouldn't ideally be used for validating in this study, i,e. remove model validation time series from analysis ◆ Define better justification for removal of depth from part of assessment which results in changing probability on east Irish coast for example (results in higher confidence).		

Confidence Parameter:	Map:	Assessment
Kinetic Energy	UKSM10	Input Data
Input Data	ProWAM wave data (NOC), CS20, CS3, NEA tidal data (NOC)	
Peak kinetic energy (kNm^{-2}) in horizontal plane for wave and tidal layers based on 300m grid Peak wave energy is derived from ABPMer 300m fine resolution model and ProWAM. ProWAM filtered to remove swell waves and verified against field measurements. Bathymetry adjusted from chart datum to MHWS.		

Maximum tidal currents derived form depth averaged currents converted to 10% above seabed using 0.847 scaling factor, which provides <15% accuracy. Classified into low, medium and high based on Connor *et al* (2006) EUNIS categories Combined peak energy for wave and tidal layers, using the highest category (low, medium, high) assigned for each of them for any given area. This combination method details that high wave energy and low tidal energy results in combined high overall energy. However the report also notes that the current and waves act on the seabed in different ways (and cannot be added together). Therefore it may not be true that a high wave category should override a low tide category completely and they may instead average to a medium overall. Justification is needed for this matrix / highest score wins approach. This is a minor point as both measure kinetic energy.
Recommendations
◆ Define better how the peak wave energy is calculated / modelled but it can be assumed to be derived using methods in previous sections that detail the wave model developed, as included in the section on wave shear stress. ◆ Consider further investigation into use of a 3 dimensional model that incorporates barocolinic flows influenced by freshwater and storms, for example the POL High Resolution Continental Shelf Model (CS20). Though we note this does not currently cover the deep sea zone west of Scotland. However there may be others that do, for example from POL, CEFAS, DHI-WE (who are involved in EUSeaMap) or ABPMer (amongst others)

Confidence Parameter:	Map:	Assessment
Kinetic Energy	UKSM10	Confidence
Confidence Type	Peak Wave Energy	
Two energy confidence layers are output, one tidal, one wave. These are not combined into one energy confidence Marine Recorder habitat data (e.g. wave exposed coasts) has been compared to peak energy by JNCC Kinetic energy due to waves divided into 3 classes. Percentage wave exposure classes falling into expected energy class used to apply performance rating. Uncertainty assigned by comparing wave height and period from ProWAM and CEFAS measured data (See Wave Parameter table above). Uncertainty combined with depth uncertainty to assign probability for U category. Levels of uncertainty for three classes assigned by integration probability U over range for each class. Output class related probabilities then multiplied by performance rating per class. Class with highest overall probability is most probable class with associated probability.		
Confidence Type	Maximum Tidal Energy	
Kinetic energy due to currents divided into 4 categories corresponding to MNCR tidal velocity categories used in EUNIS (0.5, 1.5, 3 ms^{-1} divisions). Comparison carried out of model and observations for harmonic analyses - 6 constituents accounting for 85% of tidal values. Total mean error is sum mean errors for each constituent. Total variance is sum of each six constituents. Three classes assigned. Probability distribution in each class found and integration of probability density carried out for each class. Highest level probability used to assign class. We note the report states tidal assessment could be improved with field data and not relying on error quantification		

Recommendations
◆ Consider further investigation into combining wave and tidal layers and subsequently their confidence to allow equal weighting when confidence layers are combined. ◆ Consider further investigation into using different sources of bathymetry as used in the bathymetry confidence ◆ Consider further investigation into removing model validation time series from analysis if used in both, as for wave disturbance layer

Confidence Parameter:	Map:	Assessment
Substrate	UKSM10	Input Data
Input Data	DigSBS250; the MB0103 rock/hard substrate layer; the Water Framework Directive (WFD) typology layer ; and the NOC deep sea sediment layer	
There has not been time in the study here to fully assess the input data. Instead we just concentrate on the confidence method.		
Recommendations		
◆ None		

Confidence Parameter:	Map:	Assessment
Substrate	UKSM10	Confidence
Confidence Type	Based on MESH method	
Mostly same as MESH confidence except as below, and as shown in Figure 9: 1) Substrate data only, biological ground truthing scoring removed as not relevant; and 2) A sample density / sample variability matrix score used (to replace the ground truthing density scores in the MESH substrate confidence model), used to feed into ground truthing sample density score 3) MESH confidence scores for MNCR habitat maps used where substrate supplemented by data from MNCR 4) There may also be small changes in how individual scores assessed (pers comms Helen Ellwood, JNCC)		
Recommendations		
◆ Define better guidance to include all potential outcomes documented in MESH guidance ◆ Alter confidence scoring for hard substrata 1 = remote/direct (divers)		

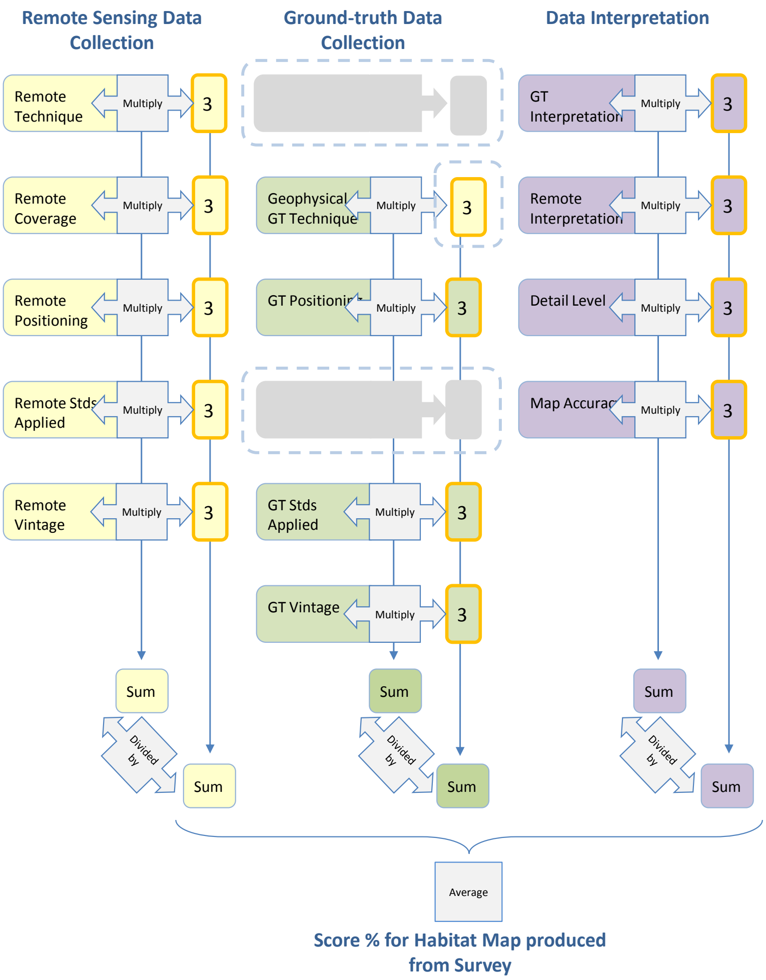

Figure 9: Diagram showing UKSeaMap 2010 Substrate Confidence Scoring Assessment, as referenced in the critique on Substrate. Method based on the MESH approach. Those objects with a grey dashed box around are altered from the MESH method (see Confidence Assessment report by MES for comparison).

2.3 Individual components of the UKSeaMap 2010 confidence assessment – a summary

Through reviewing each UKSeaMap component individually in Section 2.2, a summary list of recommendations has been compiled in Table 1. An indication of suggested improvements is provided in the last two columns under the headings of 1) Guidance (clarity required) and 2) R & D (consider further investigation).

Guidance

Whilst a number of suggested improvements have been identified, it is recognised that the UKSeaMap 2010 confidence assessment was a significant study requiring very highly skilled technical analysis, and therefore may not be repeated with full or even partial consideration of our recommendations. However a full critique has been provided for transparency.

- The main considerations for UKSeaMap in the immediate future are to clarify the report confidence documentation to ensure the understanding is correct and methods appropriate, and to consider picking out a few areas of focused study for investigation.

The reader is directed to Table 1 for full detail on how the reports could benefit from clarity in certain areas. However two of the more important clarifications needed that could have a significant impact on assessment are:

- Do various models' validation use data that was used as input to the model originally or not?
- Why was bathymetry removed from part of wave disturbance assessment as has localised impacts, which could be significant?

R & D

There are a number of recommended areas of further investigation that could be carried out. This is to be expected as UKSeaMap is based on modelled data and of course models can always be improved (but are significantly limited by resources and expense). Therefore we limit our summary points to those that are more feasible.

One of the main areas of uncertainty in UKSeaMap is for those models where there is little ground truthing data to inform the predictions. These include light attenuation where the algorithms hold no ground truthing points in the UK; and wave disturbance, which has a strong limitation of wave data in some of the UK regional seas. Therefore recommendations include:

- A study into the local tuning of light attenuation algorithms in the UK for different types of environment but especially the coast. This could be of interest to a number of parties to attract combined funding. The investigation would have to first research what local algorithms have already been applied to UK waters and to then fill the gaps. One issue however when doing this is how to merge different zones where different algorithms are applied. However research has been carried out into defining values along 'fuzzy' boundaries.
- Revisit wave validation in 5-10 years time when new wavebuoys are likely to have been set up with ongoing developments in the marine industry (e.g. renewables).

Another area that could be improved in the confidence assessment is to base maximum seabed energy not only on tidal energy but also on other sources such as barocolinic patterns and storm surges. This is particularly important in the North Sea for example and is best approached using a 3 dimensional model.

- It is recommended to update the kinetic energy using a 3 dimensional barocolinic / tidal model that covers the whole of the UK marine area together with a storm surge model. If this is not plausible currently then investigation could be made into combining different modelling approaches as carried out in the wave disturbance model.

Table 1: Summary Critique of UKSeaMap 2010 Confidence Assessment for Contributing Parameters

	Type	Recommendations	Guid-ance	R&D
Bathymetry	Data Inputs	- Consider further investigation into using date of data as in MESH. Whilst we consider this of lower weighting in MESH, if included in one habitat map should be in both. It is reported that data <100m depth is likely to be modern		*

		due to high coastal use. This infers that areas >100m could be assigned less confidence if considering ‘vintage’		
	Conf-idence	◆ Define better how SeaZone data is interpolated to 900m resolution ◆ Consider further investigation into using SeaZone depths with GEBCO values before averaging to get range of standard deviations per GEBCO cell, this information is lost ◆ Define better how standard deviations are allocated (Section A2) when looking at SeaZone + GEBCO. Implies that for non SeaZone areas, depths <250m use standard deviations for both of soundings and interpolated GEBCO areas; and for depths >250m, the maximum standard deviation of the soundings and interpolated GEBCO areas is used. We will assume this interpretation. ◆ Define better why 250m depth is used as a division between confidence methods. Would also be useful to define 250m in the categories in Figure A10. ◆ Define better Figure A11 which marks <0.1 category as grey as well as areas not included in figure so misleading, e.g. in left figure only shows categories for 200<depth<100m yet <200m is grey. Define better spatial differences in confidence method using a map, i.e. a) SeaZone, b) SeaZone + GEBCO <250m, and c) SeaZone + GEBCO >250m	*	*
Photic Depth	Data Inputs	◆ Define better the algorithm background to show it is based on a global set of data and is not locally tuned. ◆ Consider further investigation into light attenuation algorithm relevance for UK waters, either by locally tuning or using existing tuned algorithms. We recognise that it would be a significant undertaking to update the light attenuation algorithm with UK ground truthing but it could be reviewed what studies have already been carried out at a regional level. We also note that there is then an issue in how to combine different areas with different local algorithms, introducing ‘fuzzy’ boundaries. ◆ Define better the website links as does not allow access to the data. Alternative links have been provided during this review (Richard Swift, Pers. Comms.), for example: http://oceancolor.gsfc.nasa.gov/cgi/l3 and the UKSeaMap 2010 report should be updated accordingly	*	*
	Conf-idence	◆ Consider further investigation into algorithm that confidence is based on. Trend of data (predicted K490) shown in Figure B1 and replicated with annotations here in		*

		Figure 8 is shown as linear regression but data shows line should be curved (polynomial) or split into two sections above value Lw490/Lw555 = ~1. This would improve prediction at the higher end. However it is recognised that linear regression is standard for this type of ocean colour processing. ◆ Consider further investigation into bin values. In B2 Page 47, it is noted that K490 is the mid-range value of each bin. This is not true as shown in Figure B1 the predicted value at the higher end of K490 is not within the range of the actual data points plotted. This affects the confidence - as shown in Figure B2 the standard deviation increases with K490.		
Wave Disturbance	Data Inputs	◆ Consider further investigation into the confidence of offshore areas. Figure C2 shows location of the 47 wave stations, with coverage offshore in the Channel and west and north of Scotland is absent so comments re spatial differences are limited to North Sea, Outer Bristol Channel and Irish Sea. ◆ Consider obtaining a specialist peer review of data processing method as uses unpublished methods.		*
	Conf-idence	◆ Define better with regards to term 'field data' which seems to be used for post recovery site data collection – better to use 'post recovery' as referenced at start, to help reader follow process applied ◆ Consider further investigation into which of these measurement locations were used to validate the model by POL originally, those used we would expect good match anyway and is therefore circular use of data and shouldn't ideally be used for validating in this study, i.e. remove model validation time series from analysis ◆ Define better justification for removal of depth from part of assessment which results in changing probability on east Irish coast for example (results in higher confidence).	*	*
Energy	Data Inputs	◆ Define better how the peak wave energy is calculated / modelled but it can be assumed to be derived using methods in previous sections that detail the wave model developed, as included in the section on wave shear stress. ◆ Consider further investigation into use of a 3 dimensional model that incorporates barocolinic flows influenced by freshwater and storms, for example the POL High Resolution Continental Shelf Model (CS20). Though we note this does not currently cover the deep sea zone west	*	*

		of Scotland. However there may be others that do, for example from POL, CEFAS, DHI-WE (who are involved in EUSeaMap) or ABPMer (amongst others)		
	Conf-idence	◆ Consider further investigation into combining wave and tidal layers and subsequently their confidence to allow equal weighting when confidence layers are combined. ◆ Consider further investigation into using different sources of bathymetry as used in the bathymetry confidence ◆ Consider further investigation into removing model validation time series from analysis if used in both, as for wave disturbance layer		*
Substrate	Data Inputs	None		
	Conf-idence	◆ Define better guidance to include all potential outcomes documented in MESH guidance Alter confidence scoring for hard substrata 1 = remote/direct (divers)	*	

2.4 Combination of UKSeaMap confidence components

Method Used in Combination

As shown in Figure 1, the UKSeaMap 2010 contributing confidence scores for the EUNIS layers of a) biological zone, b) energy (with separate layers of tidal energy and wave energy) and c) substrate, are brought together for a single overarching confidence score by multiplying each of these together.

- It is not obvious from supporting documentation that confidence components are combined by multiplication and this could be made clearer.

The method of multiplication of the contributing confidence scores to a final score is one option and others (which may already have been considered but not seen in the literature) could include for example averaging. These are discussed further in Section 3 where trials have been carried out on the GIS confidence layers.

Relationship to the EUNIS Levels

The layers that are used to produce a standard EUNIS map differ according to the EUNIS level (3 or 4) and the coverage of substrate (rock or sediment) as detailed in the introduction. This has the following implications for the UKSeaMap 2010 confidence map:

- Whilst biological zone, energy and substrate are all relevant to mapping rock habitats at both EUNIS levels, they are not always relevant for sediment areas
- For sediment layers, energy is not considered at level 3 and at level 4 is only considered for a minority of habitats, for example tide swept areas
- For circalittoral zones the wave energy is not relevant

There is no weighting applied to contributing layers in the UKSeaMap combination of confidence layers. This is considered appropriate as EUNIS is a hierarchical system where each description applied at each level has equal importance to the final category.

2.5 Final UKSeaMap confidence categorisation

There is no categorisation provided with the final UKSeaMap confidence scores. Therefore all subsequent analysis carried out in Section 3 has been based on a simplified classification by units of 10 (0, 1-10, 11-20 etc), as was applied similarly to the MESH trials.

3 UKSeaMap Confidence Trials

3.1 Final UKSeaMap confidence classes

As no classes were set in the UKSeaMap confidence assessment, all maps have been plotted with 10 unit classes for ease of assessment.

3.2 UKSeaMap trials in alteration of component confidence scores and weightings

It has not been possible to trial any data prior to forming the individual confidence layers as this data was not made available and would not have been possible to carry out in the duration of this review.

3.3 UKSeaMap trials in alteration of combination method

The review of the UKSeaMap confidence assessment highlighted difficulties in that the final confidence currently combines all layers that might be relevant to parts of a level 4 EUNIS map. However the actual layers required at any one point depend on whether mapping sediment or rock; or level 3 or level 4. Table 2 shows the different layers used in scenarios that were chosen to best represent each combination of substrata type and level.

Each scenario has been trialled with both averaging of layers and multiplication (other than L3 Sediment which only has one confidence layer in it anyhow but is still classed as a 'scenario' for simplicity). Therefore there are 8 scenarios. Histograms showing the distribution of final confidence scores per 10 unit class and associated maps are shown in Appendix A.

A value of variance has been assigned to the UKSeaMap scenario confidence maps as demonstrated in Figure 10. The UKSeaMap variance scaling is different to MESH which showed the number of categories predicted for all scenarios. Instead, UKSeaMap variance is equal to the maximum variation of score for any one cell of the raster map, between all scenarios (both averaging and multiplication). As shown in Figure 10, the rock trials are limited to one scenario (all layers) applied to each of multiplication and averaging. Because of this, the variance has been plotted for all scenarios as well for sediment.

- It is advised that the combination method remains as multiplication owing to findings in Section 5.1 of the main report. However further numerical assessment might conclude in applying a log score to help differentiate between classes better, or not to use equal interval classes.

Note that whilst the sediment confidence assessment scenario of Biological Zone and Substrate averaged together was assessed (Figure 10), it was not considered useful to provide the results in the variance tests (Figure 11) as multiplication is considered to be a better option. However averaging has been included for rock as no other scenarios were possible in the timeframe of this review.

It is also of note that the confidence assessment scenarios for rock habitats required further investigation which was possible within the time constraints of this review. In particular the energy confidence layers need to be considered in terms of their relevance above and below the wave base and whether they should be used as two separate layers or combined into one. (Alterations to the method may have altered the results in Figure 12.) Our recommendations therefore include:

- Below the wavebase, only the tidal energy layer is relevant to the EUNIS classification. Therefore the related confidence map should be created from tidal energy alone for these parts of the map.
- Above the wavebase, both energy layers are relevant but energy is only a single component of the EUNIS classification. As detailed in Section 2.2, the peak wave energy maximum and tidal energy were left as individual layers in the confidence calculations as both were derived using different methods and are therefore not easily combined. However the actual values of energy were combined to predict EUNIS habitats (based on a matrix approach). Therefore it would be possible to re-assess the data to produce a single energy layer as proposed: If the energy category allocated matches the tidal layer then the confidence from this layer is adopted and vice versa for wave. If both tidal and wave layers contain the same energy category then the highest confidence score from each of these layers could be assigned. This would result in a single energy confidence layer that could be applied above the wave base.
- By combining the confidence from tidal only below the wave base and from both wave and tidal as proposed above for above the wavebase, a single energy confidence layer would be produced and used for EUNIS rock habitats universally.

The results of the variance calculations are shown in Figure 11 and Figure 12. The sediment map shows that the highest variance is found in the deeper ocean west and north of Scotland. This is to be expected as the data here is of the poorest quality so there is likely to be large sensitivity to the trials. This map demonstrates how accurate the data and confidence assessments need to be to inform the user of its appropriate level of use. There is also a moderate variance in sediment around the coastal seas of the UK, particularly to the north and east.

In contrast, the rock variance is much smaller and again this is to be expected as there are fewer scenarios tested. Slightly larger areas (though all are small in coverage) of high variance are found in the English Channel.

Table 2: UKSeaMap scenarios

Scenario	Biological Zone	Tidal energy	Wave energy	Substrate
L3&4 Rock above wavebase	✓	✓	✓	✓
L3&4 Rock below wavebase	✓	✓		✓
L3 Sediment				✓
L4 Sediment	✓			✓

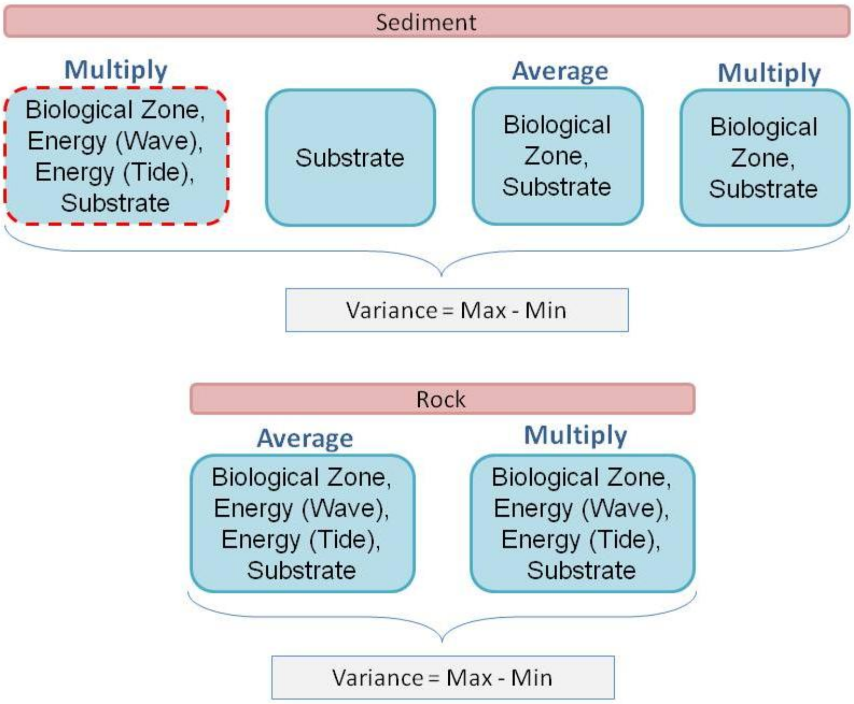

Figure 10: Calculation of variance in UKSeaMap trials. Red dashed line identifies the scenario that is not relevant for sediment EUNIS level 3 or 4 but is used as a baseline from which to calculate variance and therefore needs to be included.

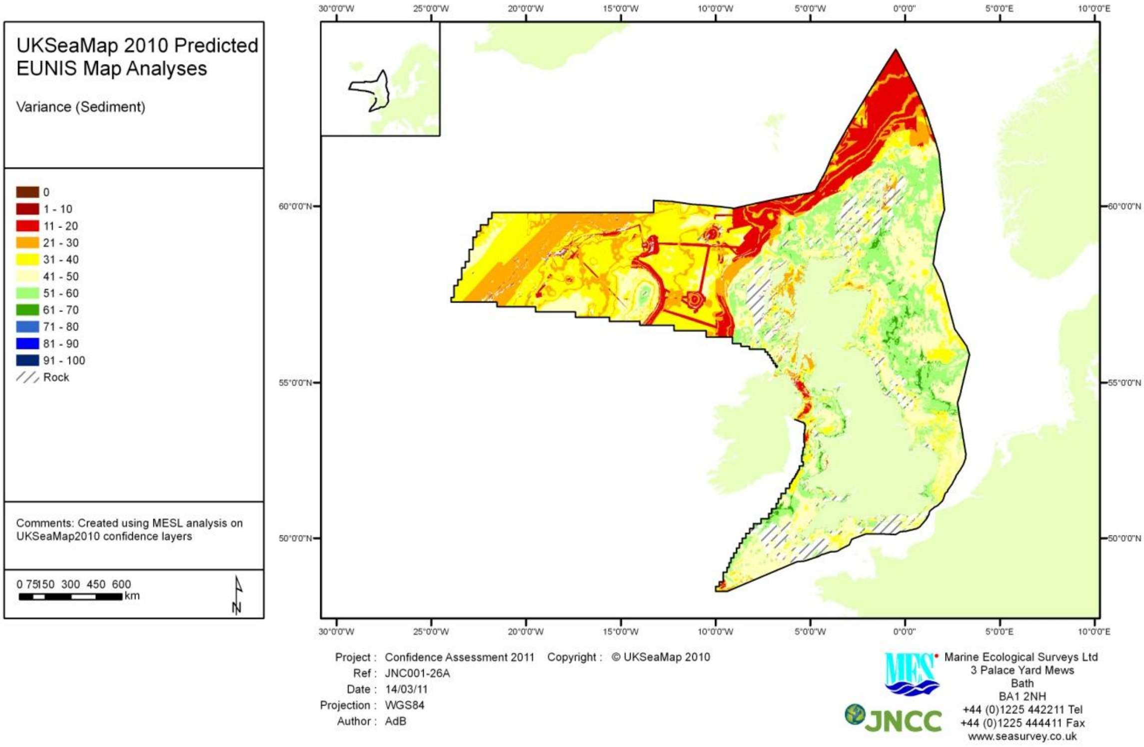

Figure 11: Variance of sediment confidence calculated in UKSeaMap scenarios, based on results from scenarios: 1) baseline, 2) substrate, 3) biological zone and substrate. All scenarios combine components through the multiplication method.

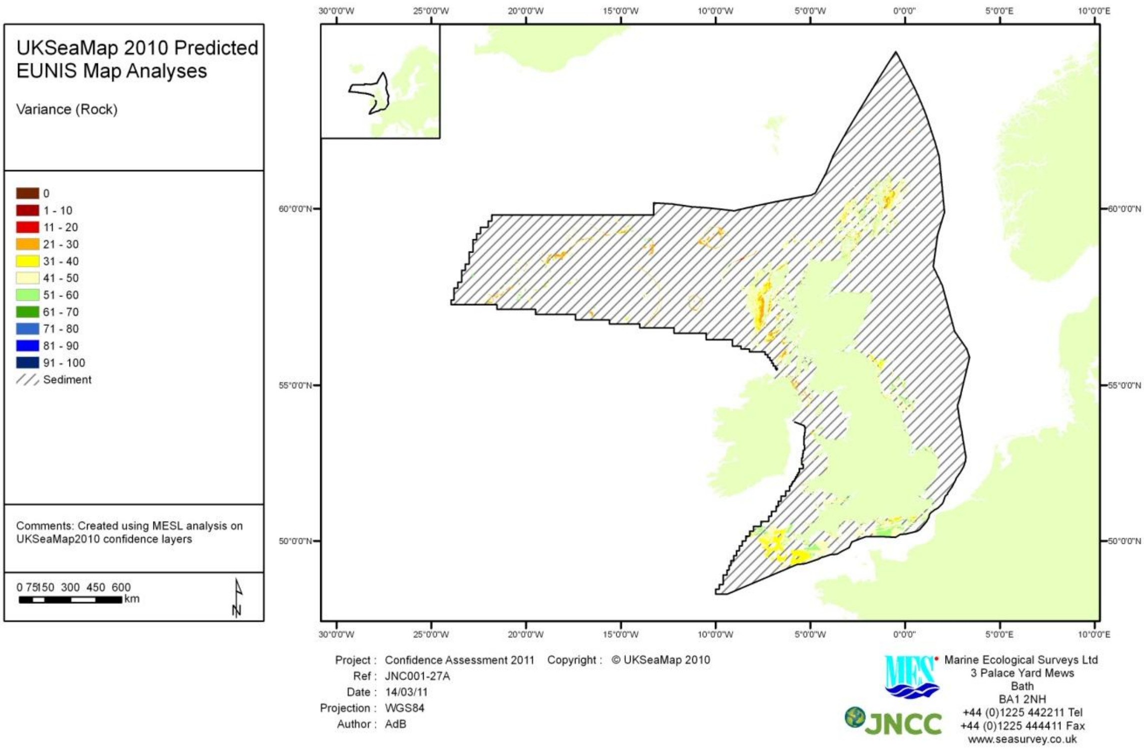

Figure 12: Variance calculated in UKSeaMap from rock scenario trials

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MESH 2008 “How much confidence should I put in a map?” Available online at http://www.searchmesh.net/Default.aspx?page=1692 [Accessed 9th May 2011].

APPENDIX A: Supporting evidence for UKSeaMap Trials

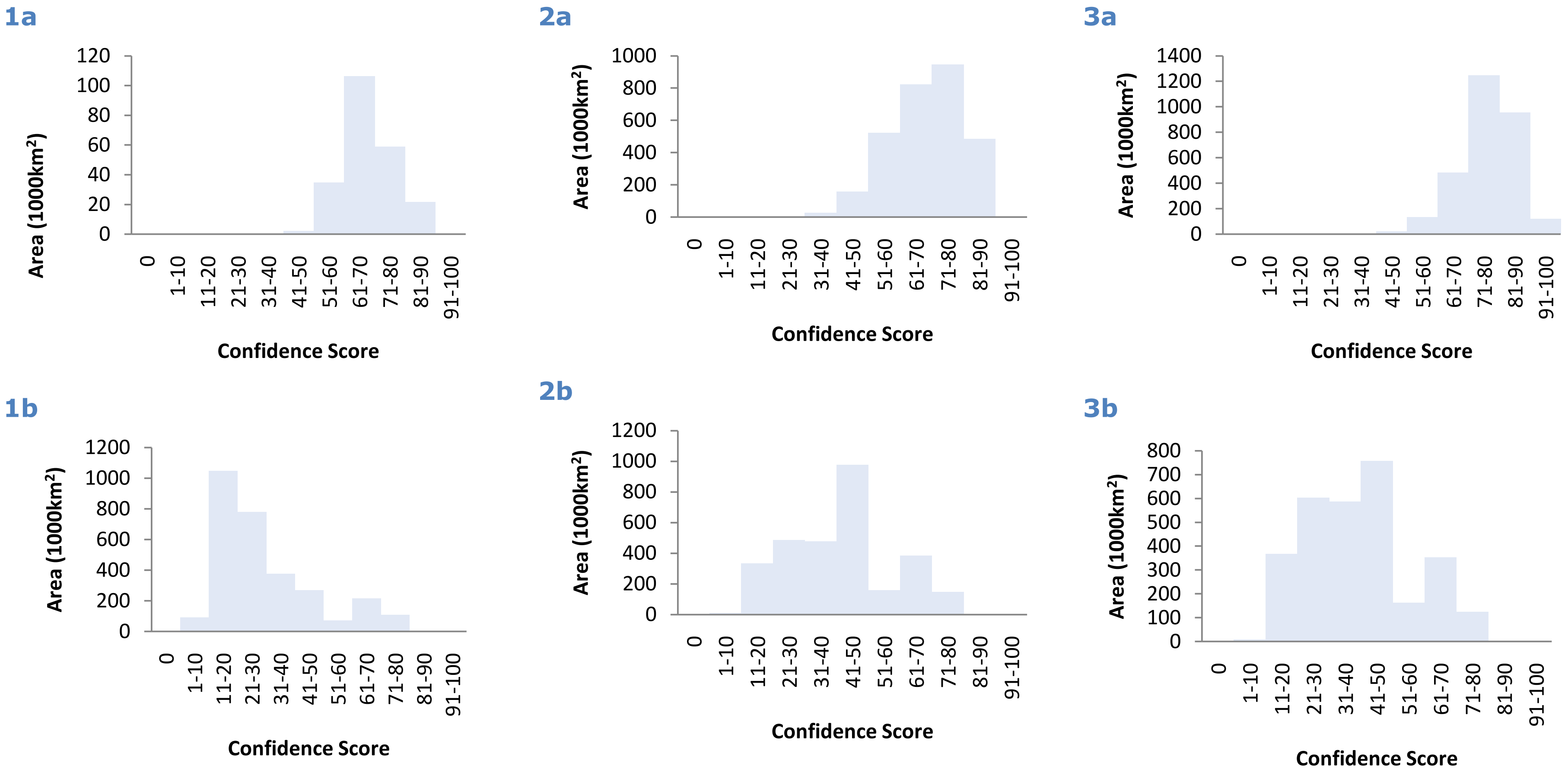

Figure 13: Histogram plots of UKSeaMap 2010 confidence score allocation by area, based on trials using 1) baseline scenario / rock EUNIS level 3 and 4 above wavebase confidence layers for (B,E_T,E_W,S) 1a) average and 1b) multiply; 2) sediment EUNIS level 4scenario (B,S) 2a) average and 2b) multiply; 3) rock EUNIS level 3 and 4 below wavebase scenario (B,E_T,S) 3a) average and 3b) multiply. Where B = biological zone confidence layer, E_T = tidal kinetic energy confidence layer, E_W = wave kinetic energy confidence layer, S = substrate confidence layer.