UKSeaMap 2010 Technical Report 2

Light penetration layer

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Contents

1 Rationale

This Technical Report describes the creation of a light penetration layer, the use of habitat data to test the boundary between the infralittoral and circalittoral zones and the creation of a light penetration confidence layer. The creation of the light penetration layer and its confidence layer were completed by ABPmer under Task 1C of the MB0102 Defra data layers contract. Greater technical detail can be found in Frost *et al*, (2010). The testing of the infralittoral-circalittoral boundary was completed by the JNCC under UKSeaMap 2010.

The fraction of light reaching the seabed is used to define the boundary between the plant dominated infralittoral and the animal dominated circalittoral zone in UK waters. A light penetration layer was required for UKSeaMap 2010 which could be used to define the boundary between these zones. The literature generally states that kelp growth requires a minimum of 1% of surface light to reach the seabed. Previously, the MESH project conducted analyses with the best available light data and habitat records to test the 1% threshold (Coltman *et al*, 2008), and revised the requirement to 2.36% of surface light reaching the seabed. As higher resolution light data and increased numbers of biological records were available for UKSeaMap 2010, the light threshold analysis was repeated.

2 Data source

Satellite observations of the diffuse attenuation coefficient of the down-welling spectral irradiance at wavelength 490 nm (K_{490}) is an effective method to provide large extent maps of light attenuation at high spatial and temporal resolution. UKSeaMap 2010 used the Kd_{490} values at a 4km resolution the Moderate Resolution Imaging Spectroradiometer (MODIS) aboard NASA's Aqua satellite[1] and the UKSeaMap 2010 bathymetry layer described in Technical Report No. 1 to produce a light penetration layer for UKSeaMap 2010 (Frost *et al*, 2010). The Kd490 product isa global dataset and is available in the form of monthly maps starting in the autumn of 2003.

3 Threshold Analysis

3.1 Method

From the 4km resolution light penetration data layer described above, D_m values were used in conjunction with depth values (-h) to create a value for the fraction of incident light reaching the seabed (Fr) using the following calculation: This fraction (Fr) of surface light which reaches a given depth is computed using the formula:

$$Fr = e^{-h/D_m}$$

where h is the depth and $D_m = K_{PAR}^{-1}$, sometimes referred to as mean penetration depth.

[1] The 4km Kd490 layer was downloaded from the NASA website (http://oceancolor.gsfc.nasa.gov/cgi/l3)

Kelp data were extracted from Marine Recorder[2] using the April 2009 version of the Marine Recorder snapshot database. In the Marine Recorder database, records are assigned attributes according to the certainty in the biotope assignment (certain or uncertain categories), and according to whether the record is a whole record with only one biotope, or a part record with multiple biotopes. Records with different combinations of these two attributes were used to see if using certain and uncertain data or whole and part records made a difference to the results (Table 1). Whole records indicate biotope description from a point source such as a grab sample while part records indicate there was more than one biotope, e.g. from a dive or video transect. Marine Recorder provides a field called 'biotope determination' which the user can use to specify whether the biotope determination was certain or uncertain. Both biotope records and kelp species records were examined.

Biotopes were assigned a 'kelp' or 'not kelp' status. Circalittoral rock biotopes were labelled as 'not kelp'. Infralittoral rock biotopes were labelled as 'kelp' only where kelp biotopes were present. Infralittoral rock biotopes where kelp biotopes were not specifically recorded (such as 'IR' or 'IR.MIR') were not examined in the final analysis. Where multiple biotopes existed for a single location, the biotopes were classed as 'kelp' if one kelp biotope was listed among the biotopes present.

Table 1: Different datasets extracted from Marine Recorder (2009 version)

Data Analyses	Analysis no.	Marine Recorder biotope determination type
All certain whole biotopes only	1.	Certain whole
All certain biotopes	2.	Certain whole Certain part
All certain and uncertain biotopes	3.	Certain whole Certain part Uncertain whole Uncertain part
Kelp species	4.	Any biotopes containing *Alaria, Laminaria* and\or *Saccorhiza* species

Hawth's tools[3] were used to enable the addition of fraction of light values from raster files to point files containing biotope or species data. Any points which had both maximum and minimum light values of zero were deleted. There were a large number of zero values due to the coarse resolution of the MODIS light data (4km), so that light data did not extend sufficiently close to the coast in many areas where habitats had been recorded. These values usually consisted of a small percentage of the overall number of points. All data were examined using Minitab v.13. Kelp biotopes were examined using both seasonal (spring, summer, autumn and winter) and annual (mean, maximum and minimum) values for fraction of incident light values.

[2] The Marine Recorder package was developed by JNCC as a collect and collate piece of software designed to hold and manage marine survey data including from Marine Nature Conservation Review surveys. The JNCC database holds benthic sample data from a variety of organisations including the JNCC, the SNCBs, MEDIN, Seasearch and Local Record Centres. See http://www.jncc.gov.uk/page-1599.

[3] Hawth's tools is a freely available extension for ArcGIS. http://www.spatialecology.com/htools/overview.php.

3.2 Results

Descriptive statistics were examined for each dataset (Table 2 - Table 5). Standard deviations were higher than the means for all datasets, indicating that the data were spread out over a large range of values. Large numbers of outliers were present in the boxplots. None of the datasets were normally distributed (p <0.05 for the Anderson-Darling normality test).

Mann Whitney U tests were carried out between 'kelp' and 'not kelp' categories for all light categories (mean, max, min, winter, spring, summer and autumn) for the certain whole records. Significant differences were present for all light categories between 'kelp' and 'not kelp' categories, with all tests having a P value less than 0.00. Seasonally, winter consistently had the highest median and 1st quartile values, followed by autumn, summer and spring. Tables 2 - 4 show very similar patterns, with the analysis by species giving noticeably different results: annual mean for kelp species (0.006) compared to kelp biotopes (0.010).

3.3 Conclusion

Based on the 1st quartile value (all certain biotopes, annual mean), the results indicate that the transition from the infralittoral to the circalittoral zones occurs when less than 1% of light reaches the seabed. The first quartile value was used as it indicates that 75% of the kelp biotopes were located in areas in which 1% of surface light reached the seabed. The difference between the MESH (2.36%) and UKSeaMap 2010 (1%) value is attributed to the higher resolution light data and increased number of biological records in the UKSeaMap 2010 analysis and the use of both certain and uncertain records in the original MESH analysis .

The MESH project sought advice regarding the critical time of year for kelp growth, to determine whether data for a particular season should be used, or an annual mean (Coltman *et al*, 2008). Professor Christine Maggs (Queen's University, Belfast, UK) advised that the maximum depth penetration of kelp is likely to be related to the annual photon density. Kelp plants store photosynthate then start growing during the winter when the light levels are low. Stimulation for the growth of a new blade begins in the short days of autumn. Gametophytes require a small amount of blue light and it is thought that any light will contain sufficient blue light. Hence there does not appear to be a critical time of year for kelp growth; the annual mean fraction of light was used to calculate the depth of the infralittoral zone.

The inclusion of uncertain records did not have a major affect on the results, indicating that that biotope determination does not have an effect on the presence of kelp. This is as expected as to classify a habitat as a kelp biotope, presumably some kelp would need to be present.

The results indicate that kelp species can exist when the surface light reaching the seabed is at lower levels with a first quartile annual mean value of 0.0058. There is no indication as to how much kelp was present in these low light areas. These records would include rare or occasional occurrences of kelp which would not be enough to classify an area as a kelp biotope

Table 2: Analysis No.1: Median and 1st quartile values for the presence and absence of kelp biotopes. N = 1,376 (kelp). N = 1,883 (not kelp).

		Median	1st quartile
Annual Mean	Kelp	0.0467	0.0101
	Not kelp	0.0076	0.0011
Max	Kelp	0.0747	0.0198
	Not kelp	0.0168	0.0036
Min	Kelp	0.0227	0.0010
	Not kelp	0.0023	0.0001
Winter	Kelp	0.0551	0.0081
	Not kelp	0.0114	0.0018
Spring	Kelp	0.0318	0.0034
	Not kelp	0.0038	0.0004
Summer	Kelp	0.0377	0.0033
	Not kelp	0.0046	0.0002
Autumn	Kelp	0.0492	0.0056
	Not kelp	0.0097	0.0013

Table 3: Analysis No. 2: Median and 1st quartile values for the presence and absence of kelp biotopes). N = 1,664 (kelp). N = 1,991 (not kelp).

		Median	1st quartile
Annual Mean	Kelp	0.0467	0.0101
	Not kelp	0.0076	0.0011
Max	Kelp	0.0723	0.0198
	Not kelp	0.0170	0.0036
Min	Kelp	0.0228	0.0012
	Not kelp	0.0023	0.0001
Winter	Kelp	0.0495	0.0081
	Not kelp	0.0114	0.0017
Spring	Kelp	0.0318	0.0043
	Not kelp	0.0041	0.0004
Summer	Kelp	0.0379	0.0033
	Not kelp	0.0052	0.0002
Autumn	Kelp	0.0492	0.0056
	Not kelp	0.0099	0.0013

Table 4: Analysis No. 3: Median and 1st quartile values for the presence and absence of kelp biotopes. N = 1,906 (kelp). N = 2,596 (not kelp).

		Median	1st quartile
Annual Mean	Kelp	0.0467	0.0101
	Not kelp	0.0077	0.0015
Max	Kelp	0.0706	0.0198
	Not kelp	0.0172	0.0031
Min	Kelp	0.0223	0.0010
	Not kelp	0.0023	0.0001
Winter	Kelp	0.0495	0.0081
	Not kelp	0.0127	0.0014
Spring	Kelp	0.0318	0.0034
	Not kelp	0.0039	0.0004
Summer	Kelp	0.0354	0.0033
	Not kelp	0.0049	0.0002
Autumn	Kelp	0.0482	0.0056
	Not kelp	0.0103	0.0013

Table 5: Analysis No. 4: Median and 1st quartile values for the presence of kelp species. N = 3,574.

	Median	1st quartile
Annual Mean	0.0436	0.0058
Max	0.0623	0.0119
Min	0.0159	0.0007
Winter	0.0465	0.0047
Spring	0.0266	0.0021
Summer	0.0320	0.0029
Autumn	0.0423	0.0031

4 Data Processing

Under Task 1C of the MB0102 Defra data contract, a light penetration layer was developed using the 4km resolution K_{490} Aqua MODIS data obtained from the SeaWiFS website (http://oceancolor.gsfc.nasa.gov/cgi/l3). The satellite data were interpolated down to a 300m grid by Inverse Distance Weighting (IDW). The light penetration layer incorporated both the K_{490} layer and the new bathymetry layer (Frost *et al*, (2010) and UKSeaMap 2010 Technical Report No. 1). Following the threshold analysis, the lower limit of the infralittoral zone was defined as the depth at which the light intensity reaching the seabed is 1% of the surface light. This is known as the photic or compensation depth. If the photic depth is greater than the water depth, then light will penetrate to the seabed and the area can be said to lie within the photic or infralittoral zone.

5 Confidence

A confidence map of the light penetration layer was produced under Task 1C of MB0102 (Frost *et al*, 2010). The confidence layer for the light penetration layer incorporated two separate uncertainty layers:

- A light uncertainty layer derived from standard deviations between the empirical K_{490} layer and in situ record were used to produce an uncertainty layer for the K_{490} layer. Comparisons between NASA satellite and *in situ* measurements[4] were used to produce a confidence layer for the light penetration layer (Frost *et al*, 2009)
- A bathymetry uncertainty layer derived from standard deviations between the bathymetry layer and depth soundings and differences between SeaZone and GEBCO data.

The final confidence map shows the probability that a given cell lies within the photic depth as specified by the requirement that 1% of the surface light reached the seabed. The light penetration confidence layer predicted confidence based on a 300m grid of depth and light penetration standard deviations.

An automated tool has been created which will allow each stage in the confidence assessment process to be repeatable using the light data.

[4] Report available from:
http://oceancolor.gsfc.nasa.gov/REPROCESSING/SeaWiFS/R5.1/k490_update.html

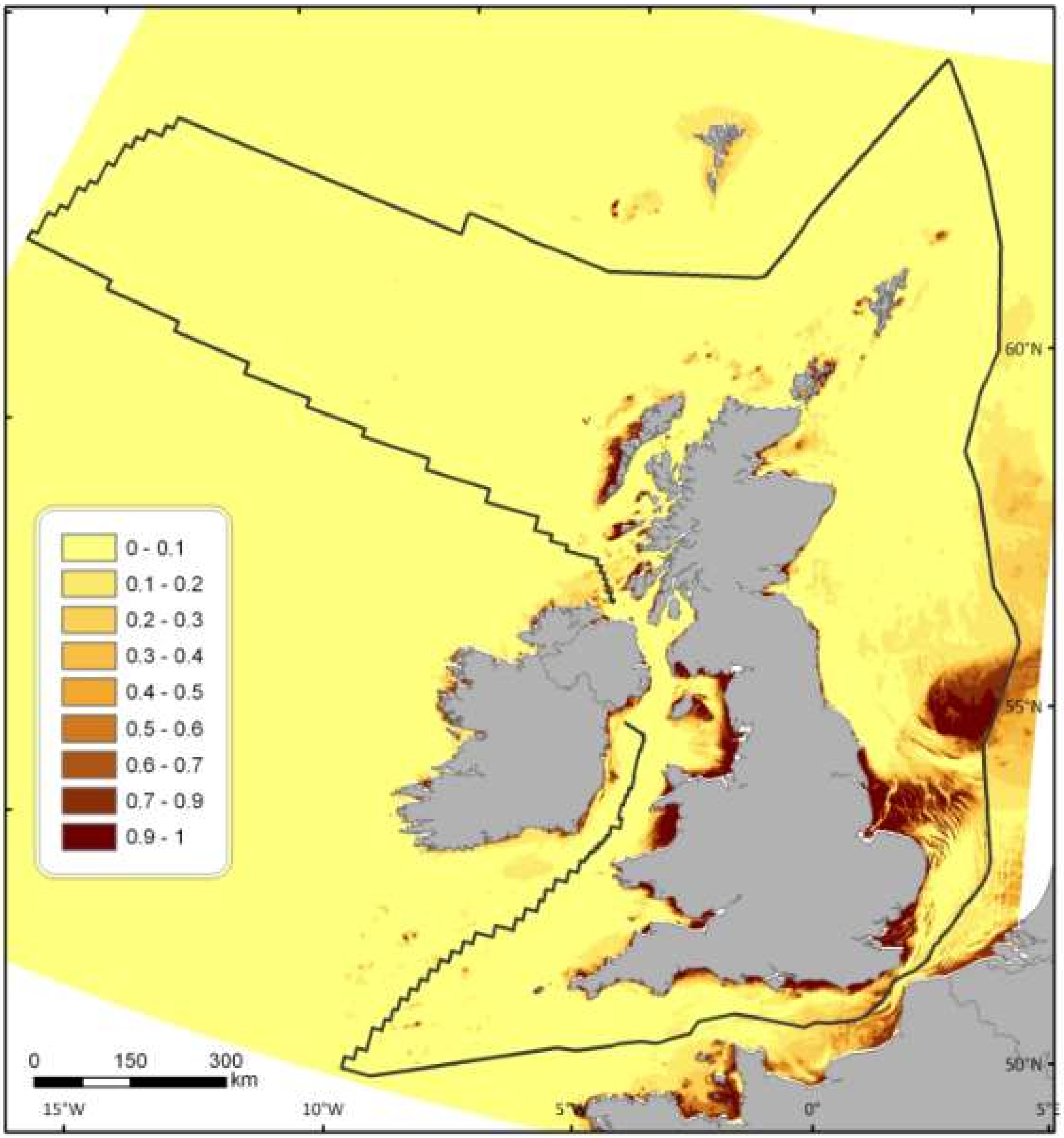

Figure 1: Probability of the infralittoral zone. The lower limit of the infralittoral zone is defined by the 1% light threshold boundary.

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