EUSeaMap

Technical Report No. X

Modelling

Contents

1 Introduction

The objective of the EUSeaMap project was not only to produce habitat maps but also to deliver a model that would allow repeatability, i.e. a model that could be rerun by persons with moderate expertise in geographic information system and no experience in computer programming.

After a recap of the different concepts used in the EUSeaMap modelling project (triplet approach and fuzzy logic), this document describes how modelling has been carried out, what models are composed of, what they need to run and what they produce.

2 Methodology: the 'triplet' approach

EUSeaMap modelling methodology builds on the MESH project 'triplet' approach, which involves the combination of three information layers (Coltman et al., 2008):

- Seabed substrate (e.g. mud, sand, rock)
- Biological zone (e.g. infralittoral, circalittoral), based on bathymetry and light variables
- Energy (e.g. low energy, moderate energy), based on variables describing wave action and tidal currents

Each of these three layers contains codes. The final habitat map is the result of a simple addition of these codes. Different units are used in each layer so that the background information is not lost when layers are combined. These units are 1's for energy codes (e.g. 2 is 'moderate energy'), 10's for seabed substrate codes (e.g. 10 is 'rock') and 100's for biological zone codes (e.g. 300 is 'deep circalittoral'). Therefore the addition of the three layers results in a layer with a 3 digits code that is quite easy to decrypt (in the above examples we would have 312, which means 'deep circalittoral' + 'rock' + 'moderate energy').

Such a 'triplet' term was relevant for the MESH study area. Within the EUSeamap project, it is relevant for the North/Celtic Seas, but it is not for the Baltic Sea, where a salinity parameter needs to be taken into account, and the Mediterranean Sea, where energy variable cannot be used.

3 Thresholds and Fuzzy logic

Computing categorical maps, for example biological zones (infralittoral, circalittoral and so on), from continuous variables, implies that a set of thresholds have to be determined. For example, in the Mediterranean Sea the threshold for infralittoral – circalittoral delimitation is 1% of light reaching the seabed, because it is considered that below this value seagrasses do no longer have light enough to grow. Above this limit the probability of being in infralittoral zone is 1, below it is 0. Symmetrically above this limit probability of being in circalittoral zone is 0, below it is 1.

But trying to classify in this way has limitations. Obviously nature is not as simple; boundaries between two habitats are not that sharp. A way to show some of the flexibility seen in real world is to use fuzzy boundaries instead of sharp ones.

Fuzzy logic involves calculations of probability derived not merely from Boolean laws, as described above, but through a fuzzy membership function. The shape of this function is governed by four control points (Roberson et al., 2004). Figure 1 illustrates the fuzzy membership function of a class, e.g. “Upper circalittoral” biological zone. In abscissa is the variable value (e.g. percentage of light at the seabed). In ordinate is the degree of membership, i.e. the probability of being in the class. Control points are a, b, c and d. Their abscissa is, respectively, ULMin (Upper Limit Minimum abscissa), ULMax (Upper Limit Maximum abscissa), LLMin (Lower Limit Minimum abscissa), and LLMax (Lower Limit Maximum abscissa).

Point ‘a’ indicates where the membership function begins to increase above 0. ‘b‘ is the point where the membership degree reaches its plateau, i.e. 1. Point ‘c’ marks the location where the membership function begins to drop below 1 and ‘d’ indicates where the membership degree again is 0. In other words before point ‘a’ and after point ‘d’, there is no doubt that we are out of the class; between points ‘b’ and ‘c’, there is no doubt that we are within the class; and between points ‘a’ and ‘b’ on the one hand (upper limit of the class) between points ‘c’ and ‘d’ on the other hand (lower limit of the class) it is “fuzzy”, fuzziness being expressed through an equation. This equation can be a simple straight line, as shown in figure 1, or a more complex function. In EUSeaMap, a straight line was used to model fuzziness.

A fuzzy membership function is not always composed of four points. If a class has only one limit because there is not any other class either above it (e.g. infralittoral zone) or below it (e.g. abyssal zone) the function will have only 2 points.

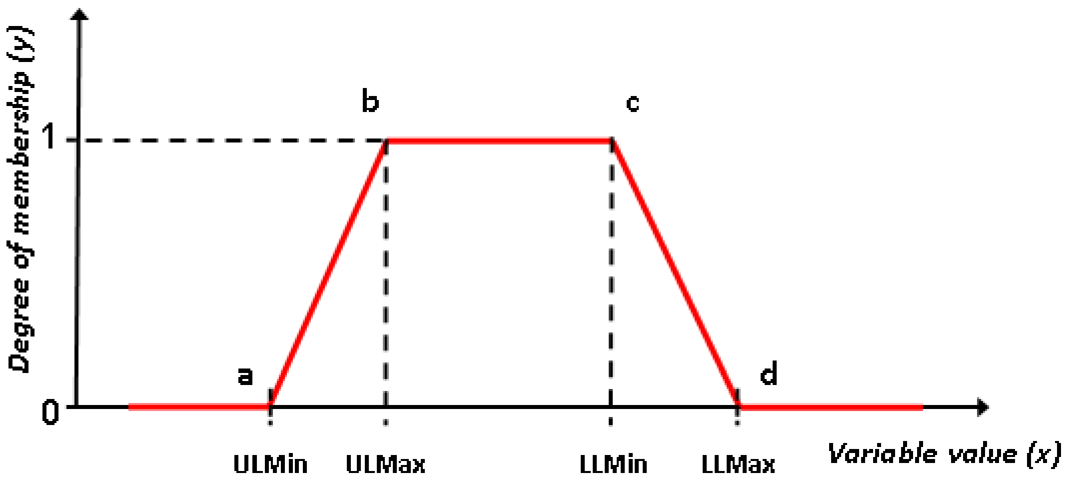

Figure 1 Fuzzy memberships function of a class (e.g. upper circalittoral biological zone). Controls points are 'a', 'b', 'c' and 'd'. From left to right, before 'a' and after 'd', likelihood is 0; between 'b' and 'c', it is 1; between 'a' and 'b' is the upper boundary of the class. There likelihood goes up from 0 to 1; between 'c' and 'd' is the lower boundary of the class. There likelihood drops from 1 to 0.

In terms of thresholds, by comparison with a Boolean classifier a fuzzy one needs more than one threshold to define a class boundary; it needs a range of values, corresponding to [ULMin, ULMax] and [LLMin, LLMax] in figure 1. These fuzzy limits are defined either from literature and expert judgment (rarely), or through testing against field data.

Having established these values, the appropriate membership fuzzy function to assign a value between 0 and 1 to each grid cell in a fuzzy membership 'score' layer is the following one.

```
When x ≤ ULMin or x ≥ LLMax, y = 0

When x ≥ ULMax and x ≤ LLMin, y = 1

When x > ULMin and x < ULMax, y = x/(ULMax - ULMin) - ULMin/(ULMax - ULMin)

When x > LLMin and x < LLMax, y = x/(LLMin - LLMax) - LLMax/( LLMin - LLMax)
```

This function has to be run for each class that comprises a given variable. Hence the result is one membership 'score' layer per class. For example for biological zones in Mediterranean Sea we will have five membership 'score' layers ('infralittoral', 'upper circalittoral', 'deep circalittoral', 'bathyal', 'abyssal'). Obviously this does not constitute a final product. It has to be simplified.

Two products can be derived from the class membership 'score' layers (figure 2):

- A 'membership' categorical layer (figure 2a) indicating to which class a given pixel belongs. This layer is obtained by picking up in the class membership 'score' layers, for each pixel, the identifier of the class which has the greatest score.
- A global 'membership score' layer (figure 2b) within which the value of a pixel is the membership score of the class which has the greatest score.

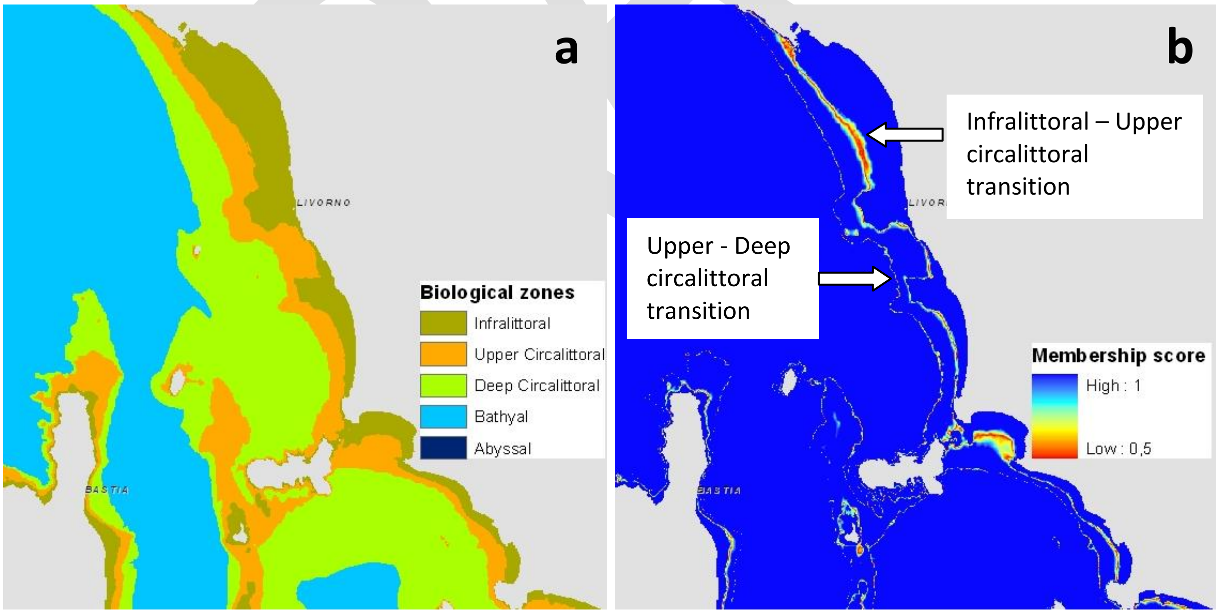

Figure 2 Products provided by a fuzzy classification (example of biological zones scheme). (a) The 'membership' layer, where the value of a pixel is the identifier of the class which has the greatest score; (b) The 'membership score' layer within which the value of a pixel is the membership score of the class which has the greatest score. While 'a' is classical categorical map, easy to understand, 'b' provides a supplemental information when clicking on a pixel in a GIS software : the likelihood of occurrence of a class; it also visually presents the tansitional zones where we move from one environment to another (non-blue coloured 'ribbons')

These two products are complementary. The former one is a classical easy-to-use categorical map. The latter one provides the user with additional information. For each pixel it indicates the likelihood of occurrence of a class, and reflects visually the transition zones where we move from one environment to another (e.g. from infralittoral to circalittoral or from low to high energy).

4 Technical considerations

Modelling within EUSeaMap Project has been carried out in raster mode, which is the most convenient and the most efficient way to combine multiple continuous variables. ESRI® ArcGIS™ 9.3 and Spatial Analyst have been used. ArcGIS™ is a GIS software. One of its modules is ModelBuilder, which allows one to design models, i.e. graphically chain together ArcGIS™ tools using the output of one tool as the input to another tool. Models designed through ModelBuilder can be saved and executed multiple times. Spatial Analyst™ is an extension of ArcGIS™, in which raster combination through the concept of 'map algebra' can be performed.

4.1 Model settings

One of the key requirements of the EUSeaMap project was that it had to be done at 300m resolution, and that the outputs had to be in geographic coordinates (latitude/longitude). As longitude length strongly varies with latitude (e.g. 1° of longitude in Madrid = 85km, whereas 1° of longitude in London = 69km) it was not possible to have the same resolution for the whole project study area. Therefore one of the main objectives was to find, for each basin covered by the project, a resolution not equal to but globally compatible with the expected 300m resolution. Partners finally agreed on a 0.0027 decimal degrees resolution in the Mediterranean Sea (which equates to a cell of 230x300m) and a 0.003 decimal degrees resolution in Celtic, North and Baltic seas (which equates to a cell of 167x333m).
For the above reason, for storage considerations and also because each basin has its own specificities (e.g. only Baltic Sea takes account of salinity) one model has been developed for each basin: one for Baltic Sea, one for North/Celtic Seas, and one for Mediterranean Sea.

The following ArcGIS environment settings were used, applied to the individual models for the basins:

Cartography settings > Cartographic coordinate system > **WGS84** (geographic coordinate system)

General settings > Extent > Specified basin lat long limits (see table 1)

Raster Analysis settings > Cell Size > Specified basin cell size (**0.003 dd** for Baltic, Celtic and North Sea, **0.0027 dd** for Mediterranean Sea)

The limits of the regions used in the modelling are set out in Table 1. A region of overlap between 8 and 13 degrees east was run for the Kattegat Sea marking the transitional area between the Baltic and North Sea. The North and Celtic areas were treated as contiguous areas; run within the same model with the same thresholds, settings and rules.

Table 1 – Latitudinal and longitudinal limits of the models. Figures are given in decimal degrees, WGS84 horizontal datum.

Region	Lat. Min.	Lat. Max.	Long. Min.	Long. Max.
Baltic Sea	53.592700	65.907700	9.418402	30.244402
North and Celtic Seas	46.836332	63.885332	-24.997816	12.997184
Western Mediterranean Sea	34.741792	44.720992	-6.1166584	16.328442

The exact areas covered by the models were limited by the spatial coverage of input datasets. The extent of the substrate layer dictates the extent of the final habitat map.

4.2 EUSeaMap toolbox

As mentioned in the introduction, one of the main challenges of the projects was to build reusable models, i.e. models that could be run repeatedly by persons with little experience in computer programming or in the use of ArcGIS™ ModelBuilder.

Thus an ArcGIS™ toolbox, called 'EUSeaMap', was built (figure 3). This toolbox is composed of three toolsets (one toolset per basin), with each toolset containing at least one main model that has to be run to build the habitat map. The toolset can also contain other models which are either called by the main model or have to be run by the user before running the main model.

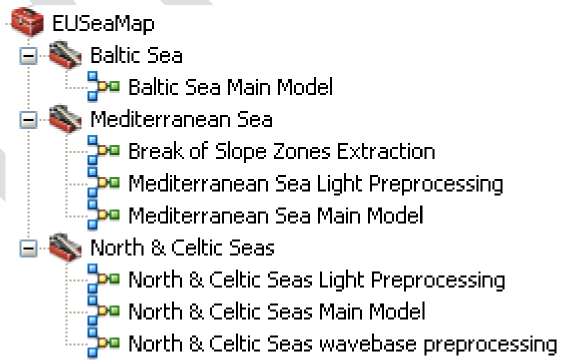

Figure 3 EUSeaMap Toolbox. It contains three toolsets (one per region), and each toolset contains at least one model, the main one. For example in Mediterranean the main model is 'Mediterranean Sea Main Model'. The other models are either loaded by the main one (e.g. 'Break of Slope Zones Extraction'), or are tools that have to be loaded by the user before launching the main model (e.g. 'Mediterranean Sea Light Preprocessing').

4.3 EUSeaMap file structure

Models and data are stored according to the following hierarchical file structure (figure 4): in the first level there are four directories, one for each model plus one named 'toolbox', which contains 'EUSeaMap.tbx' file, which is the ArcGIS™ toolbox file corresponding to the EUSeaMap toolbox described above. Within each model directory, there are four sub-directories: 'inputs' containing the data that feeds the model; 'output' into which the model writes the data it produces; 'temp' which stores the temporary data created by the model while running and 'translation_table' which contains the excel file that enables translation of the triplet codes found in the habitat map computed by the model into corresponding Eunis codes (see 'habitat translation table' section above for more details).

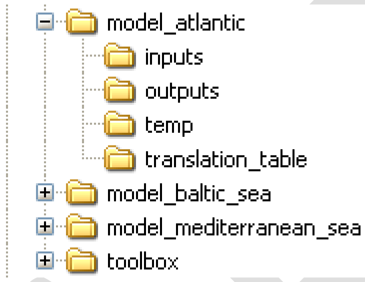

Figure 4 Modelling file structure. 'toolbox' is the directory that contains the EUseaMap toolbox file. The other directories contain information consumed or produced by each regional model. Each of these model directories (e.g. 'model_atlantic' directory, opened here) contain 4 sub-directories. 'inputs' contains the input data consumed by the model, 'outputs' contains the outputs of the model, 'temp' holds the temporary files that the model creates and in 'translation_table' directory there is the excel file that enables translation of the triplet codes into corresponding Eunis codes.

4.4 How to use the EUSeaMap toolbox

To install the EUSeaMap toolbox in an ArcMap™ document (i.e. a mxd file), right-click the 'ArcToolBox' entry in the ArcToolBox window, and click 'Add Toolbox'. Browse to the location containing the 'EUSeaMap.tbx' file ('toolbox' directory, as mentioned in the previous section), and select the file.

To launch a model in ArcMap™ ArcToolbox window one has to double click on the name of the model. This will open a dialog box allowing one to parameter the model (figure 5). The parameters are the thresholds and the input files. They are specific to a given basin. Default values are proposed for each parameter. These values are those that have been used in the scope of the project. For more details on what each parameter correspond to for a given basin see ‘Regional model description’ section.

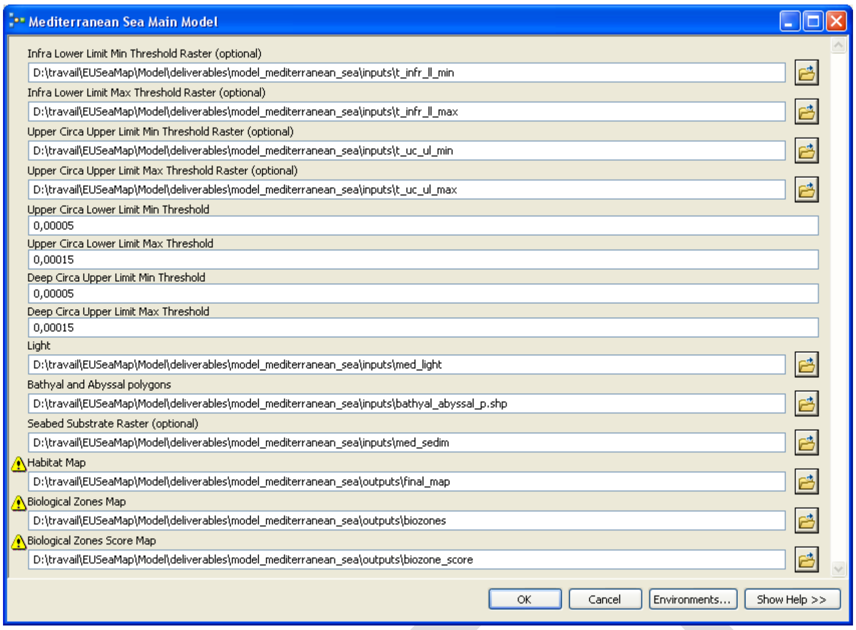

Figure 5 Example of a dialog box used to parameter a model, here the Mediterranean Sea model

4.5 Habitat translation tables

As mentioned in chapter 2, models produce habitat maps identified through triplet codes. These codes have then to be translated in Eunis. This can be done thanks to a translation table, which is in an excel file located, as seen in 'EUSeaMap file structure' section, in 'translation_table' directories.

Model code combinations were translated to EUNIS habitat types where possible. This exercise requires careful examination of the EUNIS classification system in the context of the possible combinations of physical variables that are used in the EUSeaMap models. Model code combinations were matched to EUNIS codes at level 3 and in some cases down to level 4. For the Baltic the model outputs were used to develop a proposal for the level structure of EUNIS for the Baltic region, and so the translation table relates it to proposed EUNIS habitat types, with dummy EUNIS codes.

In addition to the full detail EUNIS habitats that were predicted, the tables were adapted to include information on parent EUNIS classes, and additional aggregation classification schemes. This allows users to display the final outputs in aggregations that are suitable for different purposes.

5 Regional model descriptions

The goal of this chapter is to describe how to reuse a model if updates need to be applied (update of a layer, i.e. bathymetry, or of a threshold). In other words this section provides assistance for filling in the dialog box seen above. Therefore it describes each input the model requires and the output it produces. It also gives a short description of how the model proceeds, without going into further details.

5.1 Baltic model

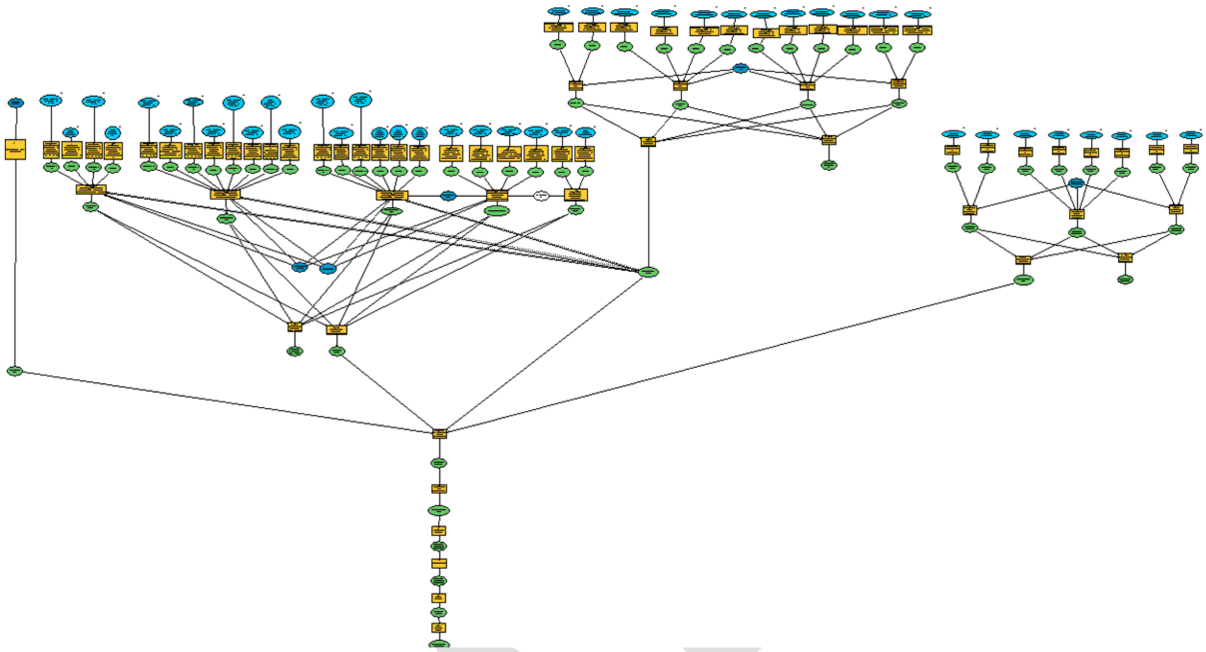

Figure 6 Screen capture of the Baltic Sea region habitat model

4.1.1. Baltic model inputs

The input layers for the Baltic basin are as follows:

Substrate

The data source was the 1:1,000,000 vector substrate map produced by the EMODNET Geology group (August 2010 release). The original map is stored in a personal GeoDatabase. The process to convert the map to a raster grid is within the main model. In order for the model to work properly the table of the layer must contain a field named 'substcode'. This is a key field because it holds the codes that the model needs to compute the triplet code. These codes are listed in table 2. For more details on the substrate layer see the Substrate technical appendix.

Table 2 – Seabed substrates of Baltic, North and Celtic Seas. and corresponding codes

Substrate	substcode
Seabed	0
Mud to Sandy Mud	1
Sand to Muddy Sand	2
Coarse Sediment	3
Mixed Sediment	4
Till	5
Rock or Reef	6

Bathymetry

The bathymetry used was that also used in the BALANCE project. For more details on the bathymetry layer see the Bathymetry technical appendix.

Light

The ratio of water depth to secchi depth. In addition a light (% at seabed) layer based on MERIS satellite data was used for polyhaline and euhaline areas as classified using the salinity layer. For more details on the light layer see the Light technical appendix.

Wavebase ratio

The wavebase ratio is the product of a preprocessing model, which implements a series of calculations (based on Soulsby, 1997) to derive the ratio of wavelength to depth, using peak wave periods across the study region. It is only used for euhaline areas as classified using the salinity layer. For more details on the wavebase ratio layer see the Energy technical appendix.

Salinity

The salinity layer is the mean value (psu). It has been estimated using calibrated and validated hydrodynamic model data averaged over several years (2000 – 2008), at a scale of ~5.5km. For more details on the salinity layer see the Salinity technical appendix.

Energy

In the Baltic model a single energy layer is used: wave energy exposure layer, pre-prepared using a high resolution fetch-based wave exposure model, amalgamated with coarse resolution oceanographic modelled data. For more details on the energy layer see the Energy technical appendix.

In addition to the above input data layers, the thresholds used in the model are requested as input parameters by the model to construct constant rasters for each threshold used in the model. All threshold parameters were specified as Data Type double, and are listed in summary Table 4. Details of the thresholds are in the corresponding Technical Appendices for the relevant variable.

4.1.2. Baltic model Outputs

The main outputs layers for the North/Celtic region are as follows:

Biological Zones Score Map – Gridded raster layer. The fuzzy membership scores associated with the final Biological Zone classification produced by the model per grid cell.

Biological Zones Map – Gridded raster layer. The final Biological Zone classification produced by the model per grid cell.

Combined Score Map – Gridded raster layer. The combined fuzzy membership scores per grid cell associated with the final classifications of energy and biological zone.

Energy Classification Map - Gridded raster layer. The energy classification (High, Medium or Low) based on energy due to waves at the seabed.

Energy Score Map - Gridded raster layer. The fuzzy membership score associated with the wave energy classification per grid cell.

Salinity Classification Map - Gridded raster layer. The salinity classification (oligohalien, mesohaline, polyhaline or euhaline) based on energy due to currents at the seabed

Salinity Score Map - Gridded raster layer. The fuzzy membership score associated with the salinity classification per grid cell.

Seabed Substrate Raster Layer – Gridded raster layer. This is the raster conversion of the input polygon substrate map.

Habitat Map Raster Layer - Gridded raster layer. The final habitat output map with ModelCode built from a combination of the Biological zone, energy, salinity and substrate class codes.

Habitat Map Polygon Layer – Polygon shapefile. The final habitat output map, to which habitat types are translated using join with the habitat translation table (based on the ModelGrid code).

In addition to these layers, the contributing fuzzy membership classes for each individual class are stored within the folder Outputs>Classes

4.1.3. Baltic model Geoprocessing

As shown in figure 2 the Baltic toolset contains only the main habitat model: all input data was pre-prepared, with the exception of the light layer that is used in Polyhaline and Euhaline regions as delineated by the model using the salinity data layer.

The Baltic model runs the geoprocessing to establish the salinity regime first, as a precondition on the biological zones and energy classification. If the salinity class is either Polyhaline or Euhaline, the model rules implemented then for the Biological and energy classes are those that are used in the North & Celtic model. The model also switches input data layers to the same as those used for the North Sea, and a as a result the outputs are identical to those predicted by the North & Celtic Seas model in the area of overlap that includes much of the Kattegat and Skagerrak Seas.

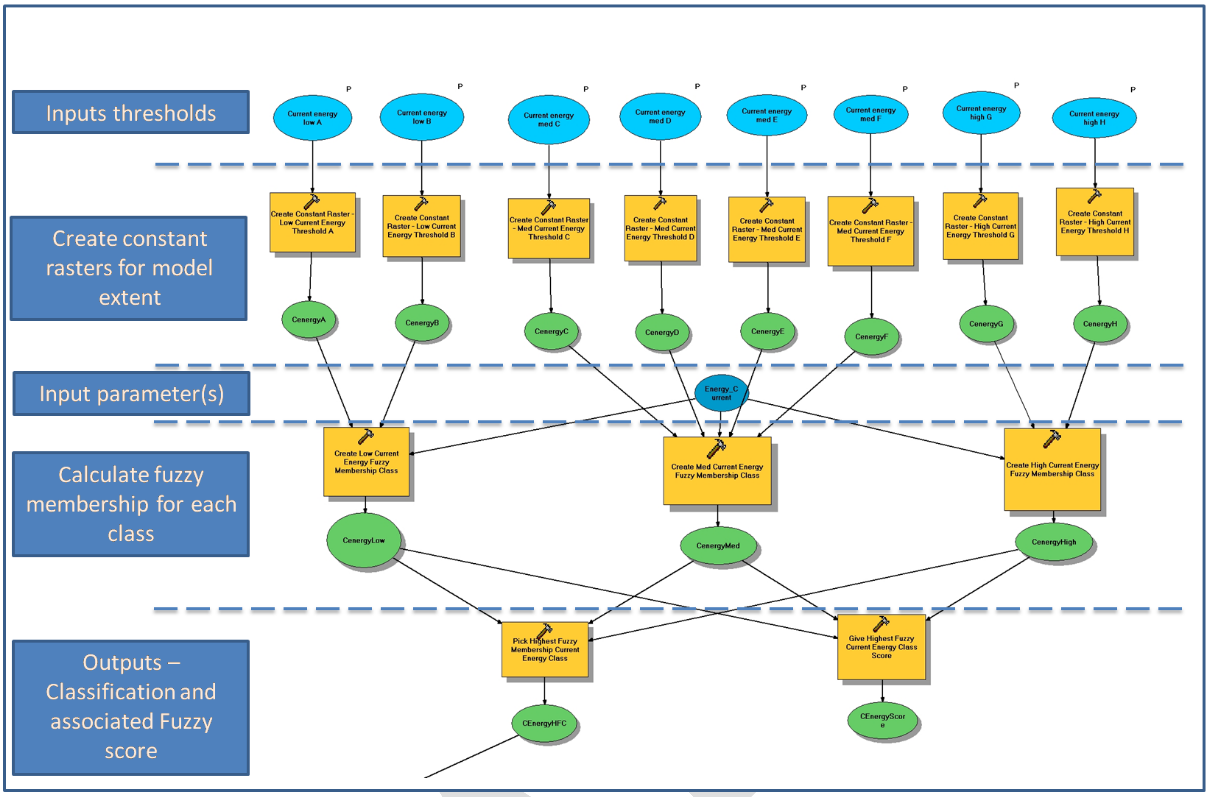

Figure 7 Annotated screen capture illustrating the geoprocessing to construct fuzzy membership values for each grid cell for each class.

Figure illustrates how the geoprocesses within the model convert the input thresholds into constant rasters which are in turn used to derive fuzzy membership functions for each grid cell. An example of the Map Algebra used to calculate these functions is given below for the infralittoral and circalittoral biological zones. The same principles are applied in the North, Celtic and Western Mediterranean models.

INFRALITTORAL

Threshold Raster name	**BioCOli**	**BioC**	**BioDOli**	**BioD**	**BioEPoly**	**BioE**	**BioFPoly**	**BioF**
Variable Raster name	n/a	Bathy	n/a	Bathy	Light	Light	Light	Light
Value	n/a	-1	n/a	1	0.011	0.0033	0.009	0.0027

con(salinityHFC == 4,con(Bathy >= 0 & Light > BioE,1,con(Light <= BioE & Light > BioF,(Light - BioF) / (BioE - BioF),0)),con(Bathy >= 0 & Light > BioEPoly, 1,con(Light <= BioEPoly & Light > BioFPoly,(Light - BioFPoly) / (BioEPoly - BioFPoly),0)))

con(salinityHFC == 3,con(Bathy >= 0 & Light > BioEPoly, 1,con(Light <= BioEPoly & Light > BioFPoly,(Light - BioFPoly) / (BioEPoly - BioFPoly),0)),con(Bathy >= 0 & Light > BioE,1,con(Light <= BioE & Light > BioF,(Light - BioF) / (BioE - BioF),0)))

CIRCALITTORAL

Threshold Raster name	**BioGPoly**	**BioG**	**BioHPoly**	**BioH**	**BioIPoly**	**BioI**	**BioJPoly**	**BioJ**
Variable Raster name	Light	Light	Light	Light	Light	Wbase	Light	Wbase
Value	0.011	0.0033	0.009	0.0027	0.0011	2.05	0.0009	1.95

con(salinityHFC == 4,con(Light > BioG,0,con(Light <= BioG & Light > BioH,(BioG - Light) / (BioG - BioH),con(Light <= BioH & Wbase > BioI,1,con(Wbase <= BioI & Wbase > BioJ,(Wbase -BioJ) / (BioI - BioJ),0)))),con(Light > BioG,0,con(Light <= BioGPoly & Light > BioHPoly,(BioGPoly - Light) / (BioGPoly - BioHPoly),con(Light <= BioHPoly & Light > BioIPoly,1,con(Light <= BioIPoly & Light > BioJPoly,(Light -BioJPoly) / (BioIPoly - BioJPoly),0)))))

con(salinityHFC == 3,con(Light > BioG,0,con(Light <= BioGPoly & Light > BioHPoly,(BioGPoly - Light) / (BioGPoly - BioHPoly),con(Light <= BioHPoly & Light > BioIPoly,1,con(Light <= BioIPoly & Light > BioJPoly,(Light -BioJPoly) / (BioIPoly - BioJPoly),0)))),con(Light > BioG,0,con(Light <= BioG & Light > BioH,(BioG - Light) / (BioG - BioH),con(Light <= BioH & Wbase > BioI,1,con(Wbase <= BioI & Wbase > BioJ,(Wbase -BioJ) / (BioI - BioJ),0)))))

5.2 North/Celtic model

4.2.1. North and Celtic model inputs

The input layers for the North/Celtic basin are as follows:

Substrate

The data source was the 1:1,000,000 vector substrate map produced by the EMODNET Geology group (August 2010 release). The original map is stored in a personal GeoDatabase. The process to convert the map to a raster grid is within the main model. The layer must contain a field named 'substcode' and this field must contain the values listed in table 2. For more details on the substrate layer see the Substrate technical appendix.

Bathymetry

Bathymetry was preprepared for the model, using the EMODNET Hydrography DEM (… release), replaced with the SeaZone Hydrospatial DEM in shallow UK waters. For more details on the bathymetry layer see the Bathymetry technical appendix.

Light

The light (% at seabed) layer is based on MERIS satellite data and used in both the polyhaline and euhaline areas as classified using the salinity layer. For more details on the light layer see the Light technical appendix.

Wavebase ratio

The wavebase ratio is the product of a preprocessing model, which implements a series of calculations (based on Soulsby, 1997) to derive the ratio of wavelength to depth, using peak wave periods across the study region. For more details on the wavebase ratio layer see the Energy technical appendix.

Salinity

The salinity layer is the mean value (psu). Salinity has been estimated using calibrated and validated hydrodynamic model data averaged over several years (2000 – 2008), at a scale of ~5.5km. For more details on the salinity ratio layer see the Salinity technical appendix.

Energy

In the North and Celtic Seas model, two energy layers are used. Kinetic energy at the seabed due to waves, and kinetic energy at the seabed due to tidal currents. For more details on the energy layers see the energy technical appendix.

In addition to the above input data layers, the thresholds used in the model are requested as input parameters by the model to construct constant rasters for each threshold used in the model. All threshold parameters were specified as Data Type double, and are listed in summary Table 4. Details of the thresholds are in the corresponding Technical Appendices for the relevant variable.

4.2.2. North and Celtic model outputs

The main outputs layers for the North/Celtic basin are as follows:

Biological Zones Score Map – Gridded raster layer. The fuzzy membership scores associated with the final Biological Zone classification produced by the model per grid cell.

Biological Zones Map – Gridded raster layer. The final Biological Zone classification produced by the model per grid cell.

Currents Energy Classification Map - Gridded raster layer. The energy classification (High, Medium or Low) based on energy due to currents at the seabed.

Currents Energy Score Map – Gridded raster layer . The fuzzy membership score associated with the current energy classification per grid cell.

Combined Score Map – Gridded raster layer. The combined fuzzy membership scores per grid cell associated with the final classifications of energy and biological zone.

Salinity Classification Map - Gridded raster layer. The salinity classification (oligohalien, mesohaline, polyhaline or euhaline) based on energy due to currents at the seabed

Salinity Score Map - Gridded raster layer. The fuzzy membership score associated with the salinity classification per grid cell.

Seabed Substrate Raster Layer – Gridded raster layer. This is the raster conversion of the input polygon substrate map.

Wave Energy Classification Map - Gridded raster layer. The energy classification (High, Medium or Low) based on energy due to waves at the seabed.

Wave Energy Score Map - Gridded raster layer. The fuzzy membership score associated with the wave energy classification per grid cell.

Habitat Map Raster Layer - Gridded raster layer. The final habitat output map with ModelCode built from a combination of the Biological zone, energy, salinity and substrate class codes.

Habitat Map Polygon Layer – Polygon shapefile. The final habitat output map, to which habitat types are translated using join with the habitat translation table (based on the ModelGrid code).

In addition to these layers, the contributing fuzzy membership classes for each individual class are stored within the folder Outputs>Classes

4.2.3. North and Celtic model geoprocessing

As shown in figure 2, the North/Celtic toolset contains three models: the sub-routine to derive wave base ratios from peak wave periods across the study region, the sub-routine to compute the percentage of light at seabed from kpar, and the main model. The subroutines have to be launched before running the main model, as they produce the required inputs. These processes are described more fully in respectively energy and light technical appendices.

The North and Celtic Seas model also runs the geoprocessing to establish the salinity regime first, as a precondition on the biological zones. This allows the model to implement different rules for the polyhaline region in the Skagerrak and Kattegat Seas. The salinity regime effectively becomes the dividing line; the switch between North/Celtic model and the Baltic model happens at the interface between Mesohaline and Polyhaline.

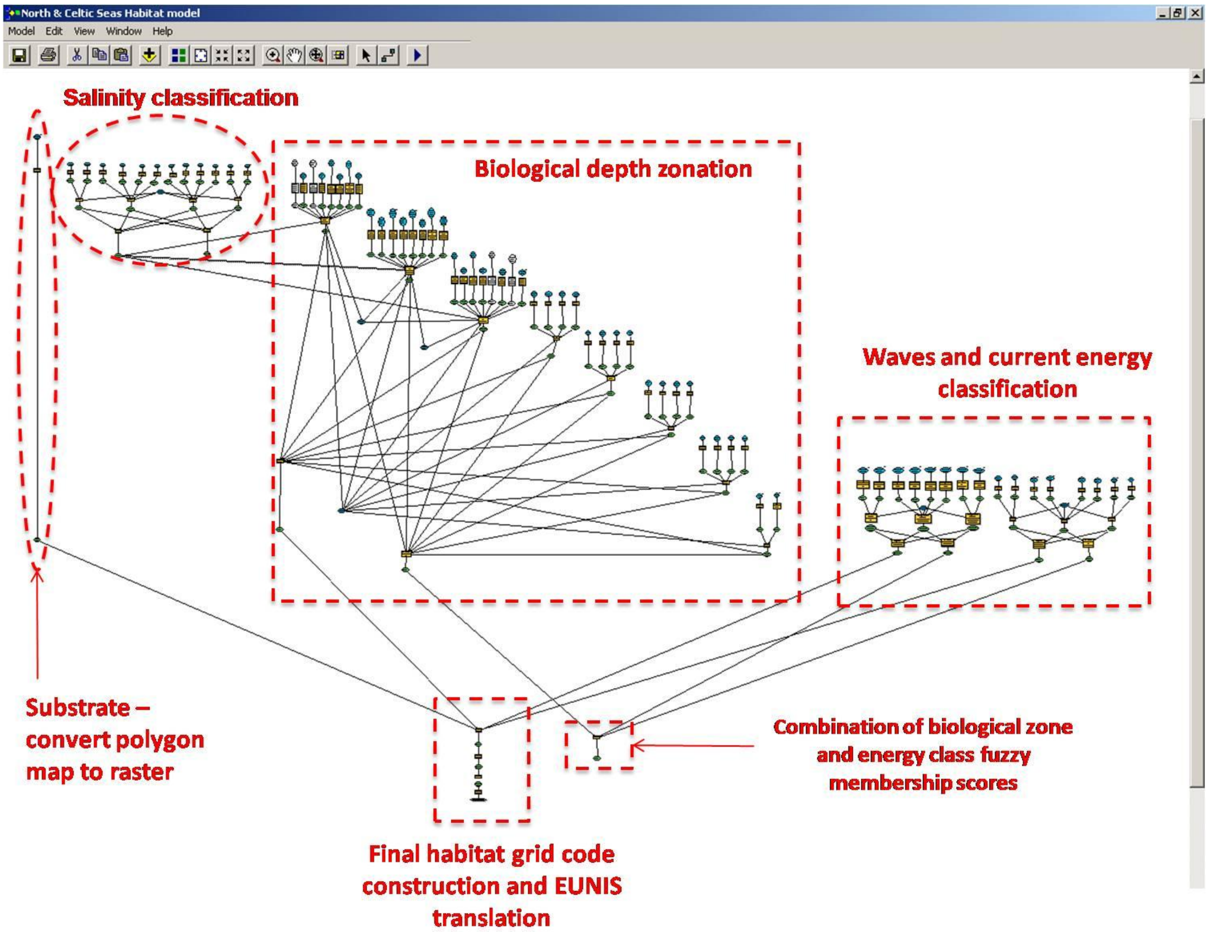

Figure 8 Screen capture of the North and Celtic sea basins' habitat model

5.3 Western Mediterranean model

One particularity of western Mediterranean basin is that only one physical variable is used in the model: percentage of light at seabed. Hence only one classification layer, the biological zones, has to be computed, and the final calculation, which performs the addition of these biological zones and the seabed substrates, results in a 'doublet' code. Another particularity is that because of Mediterranean Sea exceptional geomorphology (abrupt break of slopes) both circalittoral/bathyal and bathyal/abyssal delimitations are not derived from bathymetry thresholds, but were manually interpreted from the bathymetry layer.

The input layers for the Mediterranean basin are as follows:

Substrate

For copyright reasons the original substrate polygon layer can not be delivered. Thus the input of the Mediterranean model is a raster layer with a 0.0027 dd pixel size. The pixel values must be those listed in table 3. For more details on the substrate layer see the Substrate technical appendix.

Table 3 – Seabed substrates of Mediterranean Sea and corresponding codes

Substrate	value
Rock	10
Coarse & mixed sediment	20
Sand	30
Sandy Mud	40
Muddy Sand	50
Sand	60
Posidonia oceanica	70
Cymodocea nodosa	80

Bathymetry

Bathymetry layer is multisource. For more details on the bathymetry layer see the Bathymetry technical appendix.

Light

The light input layer is the percentage at seabed. For more details on the light layer see the Light technical appendix.

Bathyal and Abyssal polygon layer

This polygon layer contains two polygons corresponding to the bathyal and the abyssal zones. In the 'CODE' field of the attribute table the bathyal polygon is given '1' value and the abyssal polygon is given '2' value. For more details on the how the limits of these polygons were elaborated see the bathymetry technical appendix.

In addition to the above input data layers, the thresholds used in the model are requested as input parameters. These threshold values are required to construct constant rasters for each model, except for the infralittoral lower limit and upper circalittoral upper limit. For these two limits, rather than providing a single value for each fuzzy membership function

control point (see fuzzy logic section), thresholds raster layers have to be provided because the value corresponding to these control points is not spatially constant. For example the percentage of light value corresponding to the 'a' control point of the upper circalittoral upper limit is 6.0 in gulf of Lion, while it is 1.1 elsewhere. Hence a raster layer containing two values (6.0 in gulf of Lion, 1.1 elsewhere) is provided to the model through the 'Upper Circa Upper Limit Max Threshold Raster' parameter of the dialog box.
All threshold parameters were specified as Data Type double, and are listed in summary Table 4. Details of the thresholds are in the corresponding Technical Appendices for the relevant variable.

4.2.4. Mediterranean model outputs

The main outputs layers for the Mediterranean basin are as follows:

Biological Zones Score Map – Gridded raster layer. The fuzzy membership scores associated with the final Biological Zone classification produced by the model per grid cell.

Biological Zones Map – Gridded raster layer. The final Biological Zone classification produced by the model per grid cell.

Habitat Map Raster Layer - Gridded raster layer. The final habitat output map with ModelCode built from a combination of the Biological zone and substrate class codes.

Habitat Map Polygon Layer – Polygon shapefile. The final habitat output map, to which habitat types are translated using join with the habitat translation table (based on the ModelGrid code).

4.2.5. Mediterranean model geoprocessing

As shown in figure 2, the Mediterranean toolset contains three models: the sub-routine to compute the percentage of light at seabed from kpar, the subroutine to extract biological zones that depend on the break of slope limits, and the main model. The first subroutine has to be launched before running the main model, as it produces the required light input. The subroutine that extracts biological zones depending on the break of slope limits is not stand-alone. It is launched by the main model.
Figure 9 illustrates the key steps of the model. It first converts the input thresholds into constant rasters which are in turn used to derive fuzzy membership functions for each grid cell. Then it transforms the bathyal and abyssal polygon layer into three raster layers (‘shelf’, ‘bathyal zone’ and ‘abyssal zone’), calculates the fuzzy membership for each biological zone, computes the global fuzzy score layer and the biological zones, and finally performs the habitat map calculation.

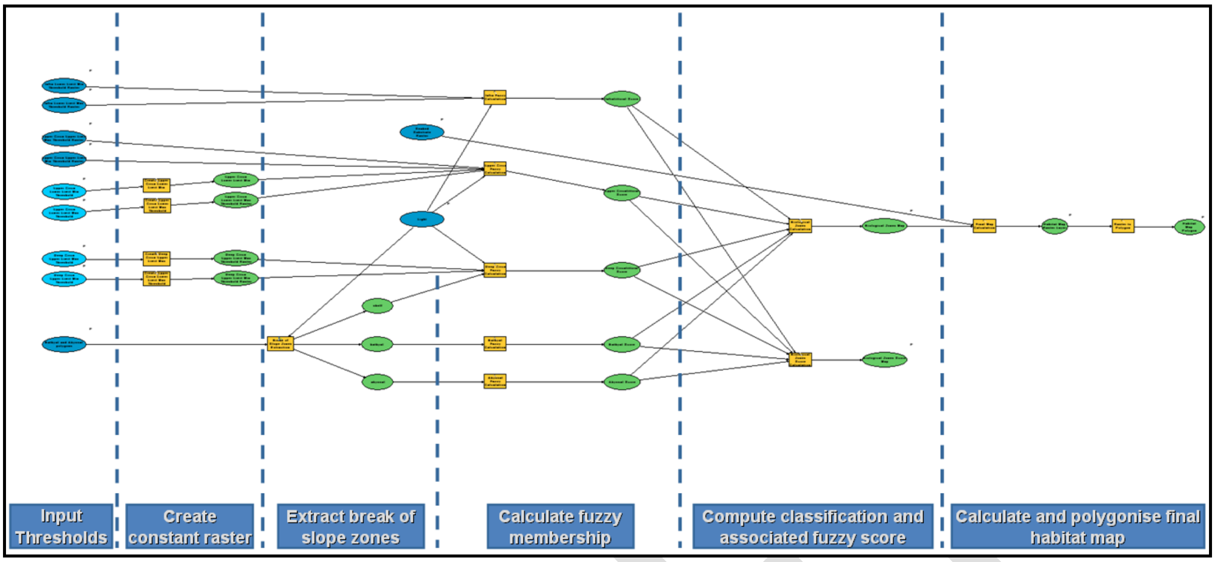

Figure 9 **Screen capture of Mediterranean Sea basin's habitat model**

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