Mapping European Seabed Habitats in the Atlantic

GIS Workshop: Habitat Mapping Using ArcGIS Tools

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Habitat Mapping

Substrate and biotopes can be spatially delineated from remotely sensed data of the seabed using ArcGIS tools. Multibeam echosounder (MBES) backscatter can be classified into acoustic classes which in turn can be refined into more detailed habitats using data from overlapping sample data with information on sediment type and/or biological assemblages.

This document will endeavour to describe different methodologies, both manual and automated, that can be used to generate habitat maps.

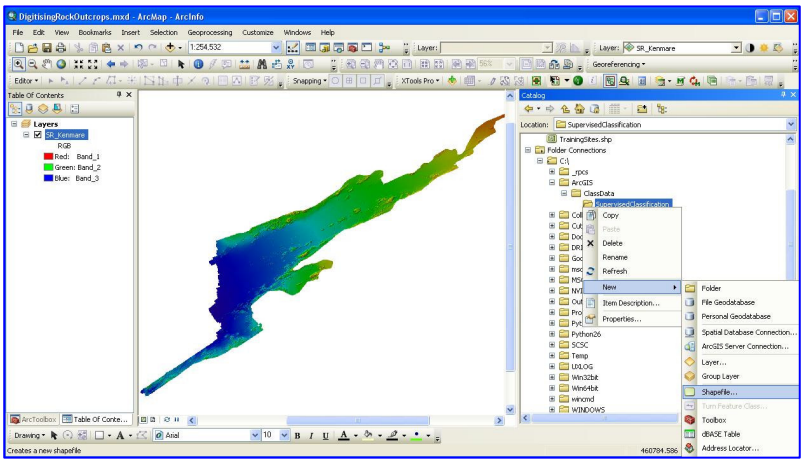
Manual Classification

The first step involved in generating a EUNIS habitat map from acoustic survey data is the separation of the data into hard and soft substrates. Rock outcrops are clearly visible on Shaded Relief imagery and the simplest method of mapping these reef habitats is by tracing the extent of the outcrop highlighted on the image.

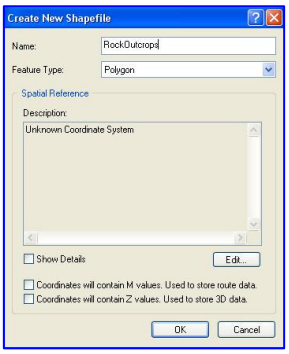
Digitising Rock Outcrops

The process is surmised in the following steps:
(i) Create a polygon file in which to store the traced polygon features i.e. rock outcrops.

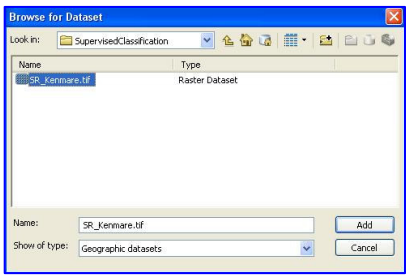
Open a new map in ArcMap and add the shaded relief image, "SR_Kenmare" (C\ArcGIS\ClassData\SupervisedClassification), to the map. Then, click on the ArcCatalog icon in ArcMap, the Catalogue Tree appears on the right-hand side of the viewer. Navigate to the "SupervisedClassification" folder in the tree, then right-click this folder and select the ***New-Shapefile*** command.



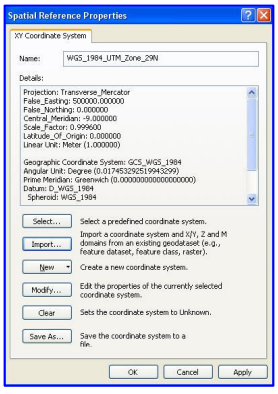
A dialogue box appears requesting the user to specify a name, a file type and a coordinate system. Type in "RockOutcrops" as the name of the shapefile and select Polygon as the Feature Type from the dropdown menu.



Next, assign a coordinate system to the new shapefile. This can be done by selecting from a predefined list of coordinate systems or by simply importing the coordinate system of an existing shapefile or raster. Click on Edit button and choose the Import option from the resulting dialogue box. Then navigate to the SuprevisedClassification folder where the shaded relief image, "SR_Kenmare", is stored.



When located, select the image and click Add. The UTM Zone 29N coordinate system can now be assigned to the newly generated polygon shapefile.

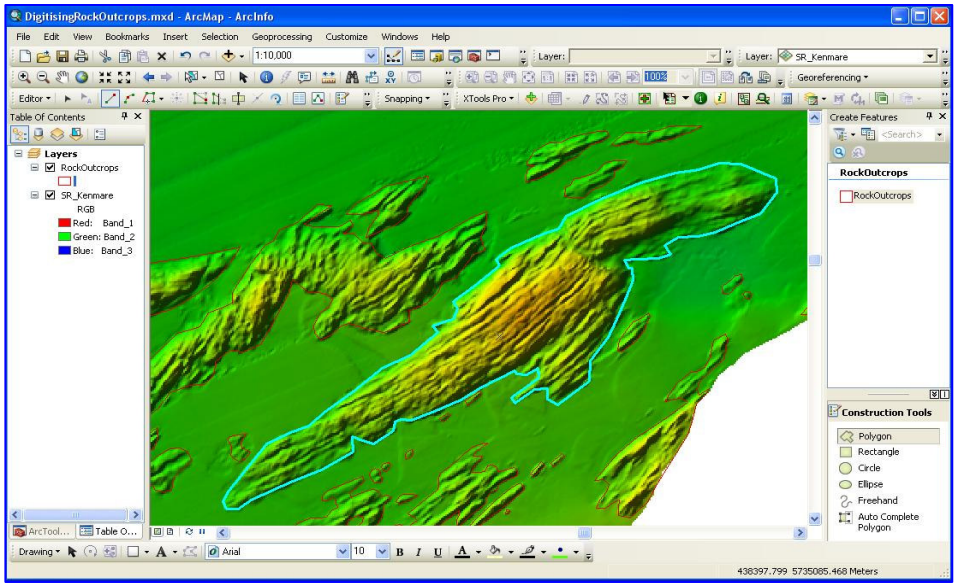


Click Apply and OK to save the actions, and OK again to close all dialogues. The "RockOutcrop" file can now be added to ArcMap for editing.

(ii) Overlay the polygon file on the shaded relief imagery in ArcMap (Use the Add Data icon  to add the "RockOutcrops" file to the existing map using the following pathway: C\ArcGIS\ClassData\SupervisedClassification).

(iii) Trace the rock outcrops when in Edit mode.

Begin an editing session by clicking on the ***Start Editing*** command from the Editor Toolbar dropdown. (If the Editor toolbar is not visible, it may need to be added, just go to ***Tools-Customise*** and tick Editor from the list of toolbars). Specify the "Rock Outcrops" file as the file that is to be edited. Zoom into an area (keep scale at 1:10000) using the zoom tool and then click on the ***Polygon*** tool in the Construction Tools Panal (in the lower left window of the viewer). Click once on the map to begin tracing, and click once each time there is a change of direction, when the outcrop has been fully traced, double-click to end. Move on to the next outcrop and repeat the procedure until all the rock outcrops have been traced. Click on ***the Edit-Save Edits*** command from the Editor Toolbar dropdown menu to save all the digitised reefs.

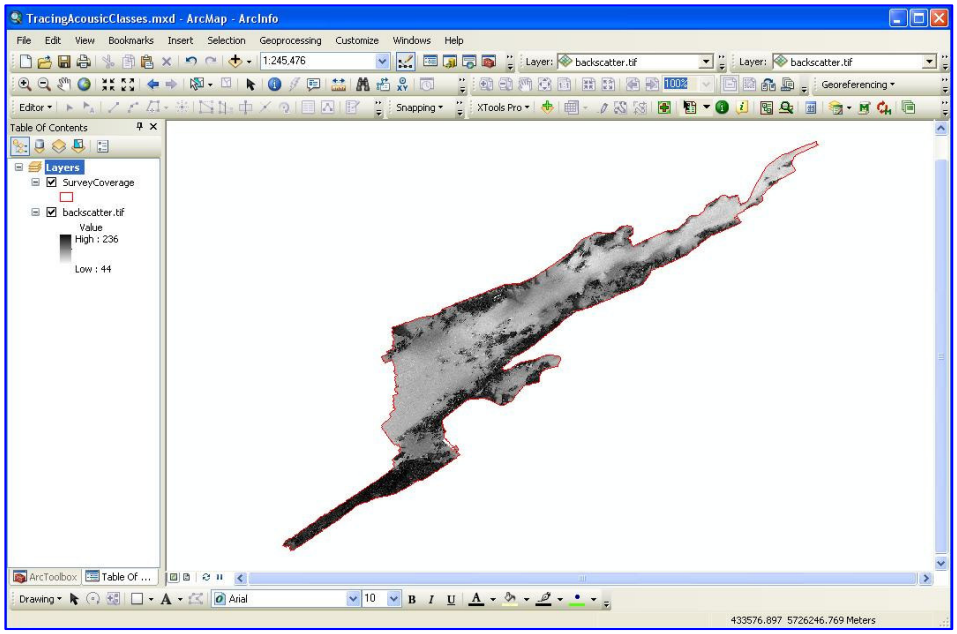


The rock outcrop layer as it is stands corresponds to a EUNIS level 2 map. To generate a higher level EUNIS map, ground truth data in the form of video drops will be used to classify the rock outcrops into biotopes. (This will be covered in detail in the Maximum Likelihood Classification section further on).

Tracing Soft Substrates

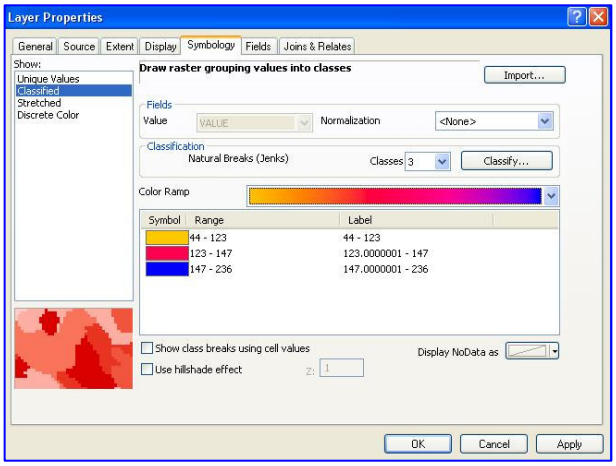
MBES backscatter imagery displays the strength of the returning echo. Different amplitudes correspond to different substrates and can be grouped into similar acoustic classes as a proxy for sediment type. The simplest way to delineate different substrates using backscatter is to view the image initially in greyscale to see how many acoustic groups can be made by a visual inspection. When decided on the number of acoustic groups present, the user can classify the image into this number of acoustic ranges and colour-code it accordingly. In the following example the data are classed into 3 acoustic groups.

Open ArcMap and add the backscatter data for Kenmare, "*backscatter*", using the following pathway: C\ArcGIS\classData\SupervisedClassification.

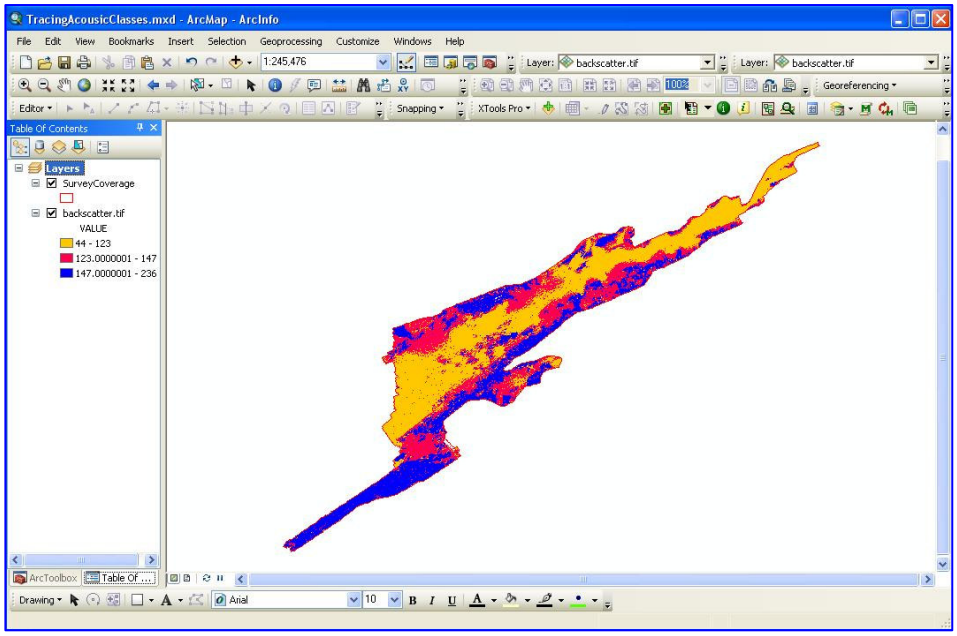


A visual inspection of the image shows that there are at least 3 different acoustic classes present: low, medium and high. In order to define the boundaries of these classes more clearly, the data can be colour-coded to display the 3 acoustic ranges.

Click on the name of the backscatter image in the Table of Contents (TOC) on the left-hand side of the screen. The Layer Properties dialogue will open, hit on the Symbology tab and a new menu opens.



Select ***Classified*** as the method for displaying the data and select "3" as the number of classes from the Classes dropdown menu. *(Natural Breaks is the default Classification Method, if the user wishes to manually put in values for the range breaks, or view a frequency histogram of all backscatter values, then click on the* ***Classify*** *button).* When satisfied with the range and number of classes, choose a colour ramp from the dropdown list and click OK.



The final step requires converting these acoustic groups into vector format for further processing and groundtruthing. This can be done by tracing the classes from the colour-coded backscatter following the exact same steps used in the "Digitising Rock Outcrops" section. (i.e. create a new polygon file and trace the extent of each acoustic class when in Edit mode).

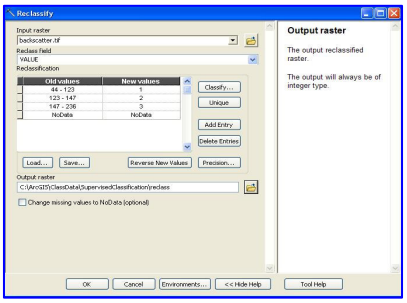
Unsupervised Classification

This classification technique involves grouping data into classes with similar acoustical characteristics.

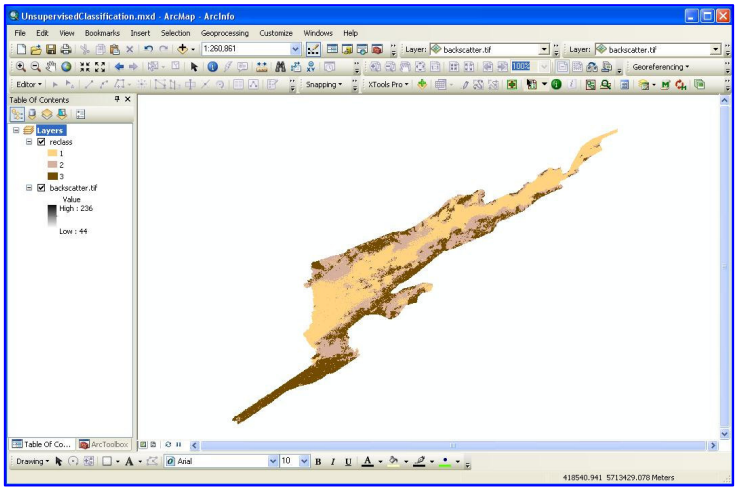
Generating Acoustic Classes

As an alternative to tracing the acoustic classes, the colour-coded backscatter data can be automatically converted into a shapefile delineating the acoustic classes using ArcTools in 2 steps:

(1) Reclass the backscatter tiff into an ArcGIS grid displaying 3 classes
This step is necessary as the acoustic data ranges need to be saved into a new raster before a polygon displaying the classes can be generated. Click on the ArcToolbox icon  and browse for the ***Reclassify*** tool which is located in the Spatial Analyst Toolbox (ArcToolbox\Spatial Analyst Tools\Reclass). Click on the ***Reclassify*** tool to open the dialogue box.

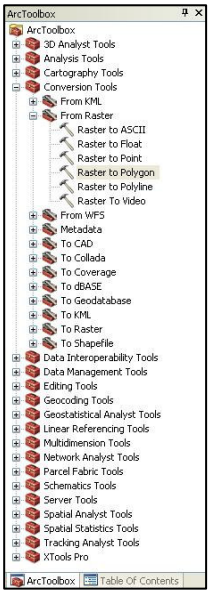


Specify "backscatter.tiff" (in its current display showing 3 acoustic ranges) as the Input raster, ensure Value is specified as the Reclass field. The current acoustic ranges should be listed as the Old values and integers, "1", "2" and "3" listed as the New values. Give the Output raster a name, "*reclass*", and save it to the "SupervisedClassification" folder. Click ***OK.*** The new raster will appear in ArcMap

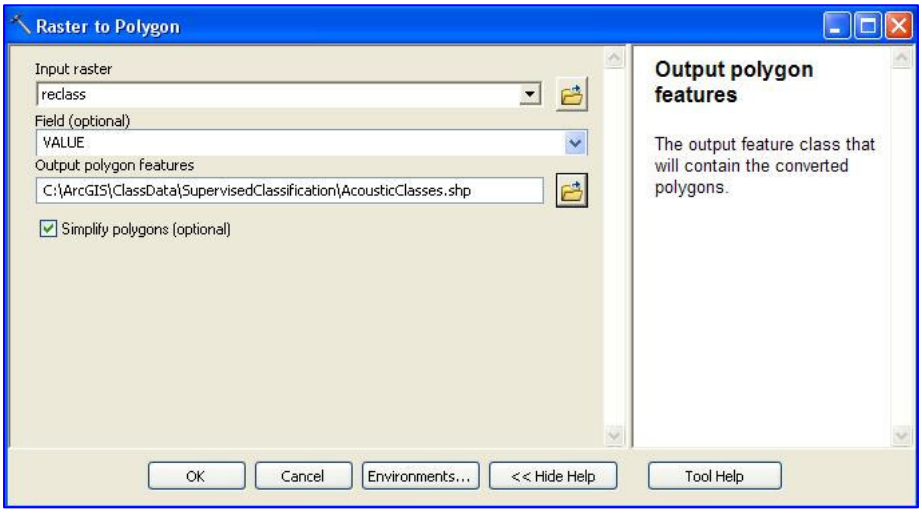


(2) Convert reclassed raster into a polygon

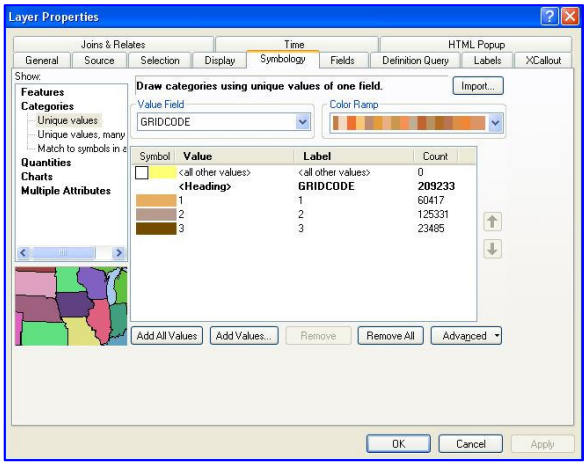
It is necessary to convert the reclassed raster into a polygon so that it can be merged with the reef data to provide a complete map of substrates within the study area. In ArcTools, select the "Raster to Polygon" tool.



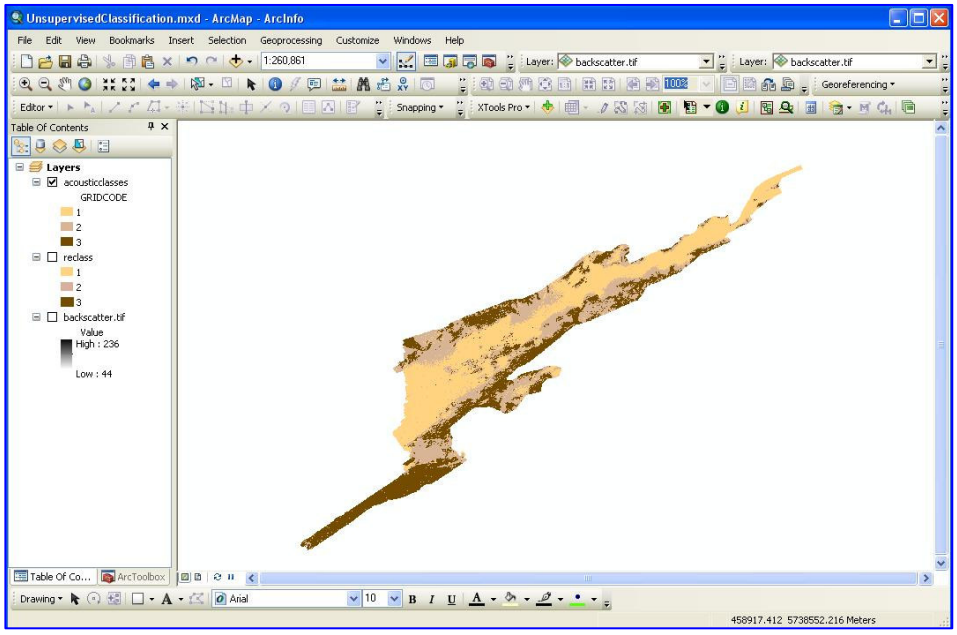
A dialogue box will appear once the tool is selected. Select the "reclass" raster as the Input raster (the "Value" attribute will automatically be entered in the Field box). Give a name to the Output file, call it "AcousticClasses" and save it to the "SupervisedClassification" folder.



A polygon shapefile displaying the three acoustic classes will now be added to ArcMap. Click on the Layer Properties of the shapefile to symbolise the data by its "gridcode" attribute. *(Click on the name of "AcousticClasses" shapefile in the Table of Contents on the left-hand side of the screen. The Layer Properties dialogue will open, hit on the Symbology tab and a new menu opens).*



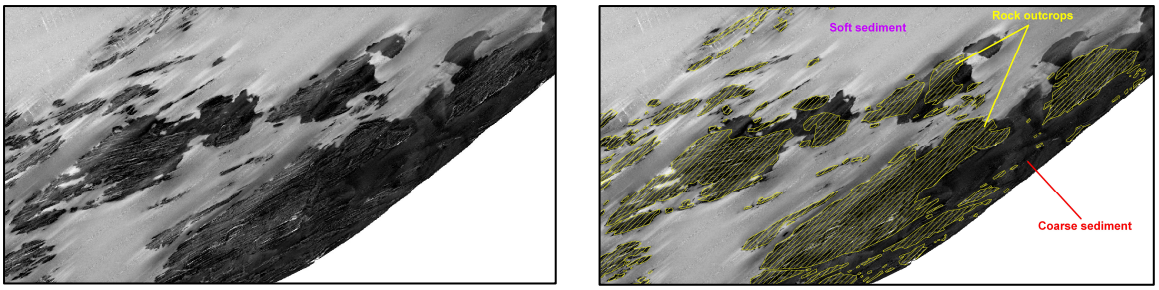
Select ***Unique values*** from the list of categories in the display options and specify "Gridcode" as the Value Field. A map showing an unsupervised classification of substrates for the study area can now be displayed in ArcMap.



The last step involves merging the reef data with the acoustic classes. In order to avoid any areas of overlap between the polygon features, the "AcousticClasses" layer will be clipped using the" RockOutcrops" layer.

Distinguishing Between Rock and Coarse Sediments

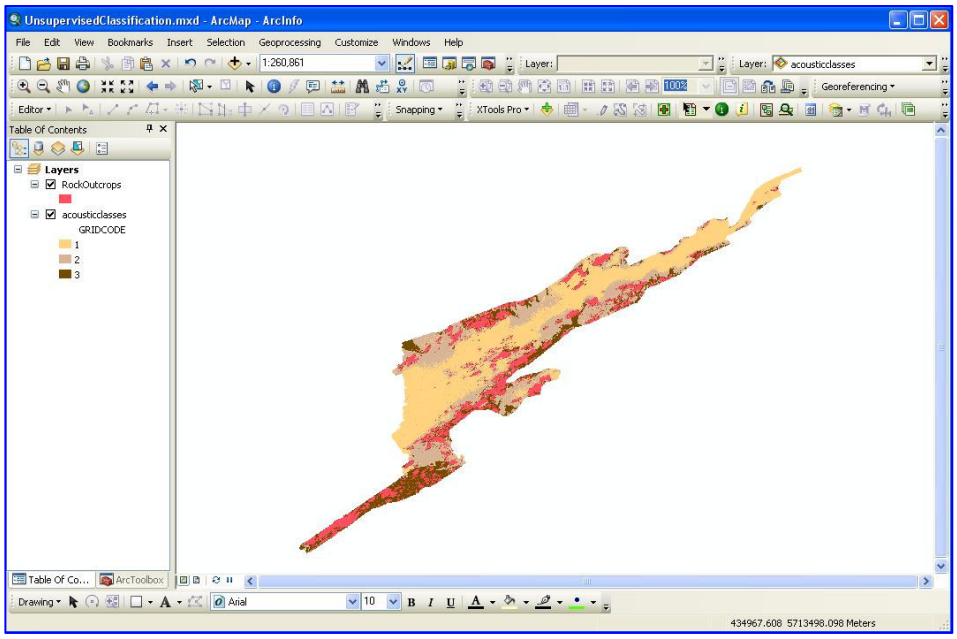
There is little difference in the strength of the returning signal when reflected off of rock and very coarse sediments, therefore, it is difficult to distinguish between these two substrates using backscatter alone (See Fig. 10).



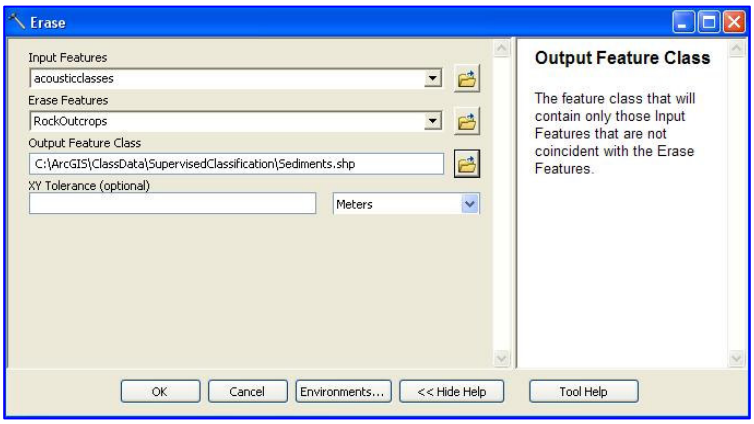
(a) (b)

Fig. 10. MBES backscatter image displayed in greyscale. (a) Darker shades correspond to rock and gravels, paler shades correspond to softer sediments such as muds and sands. (b) Rock outcrops traced from shaded relief imagery can be overlain on the backscatter to help distinguish between coarse sediments and rock.

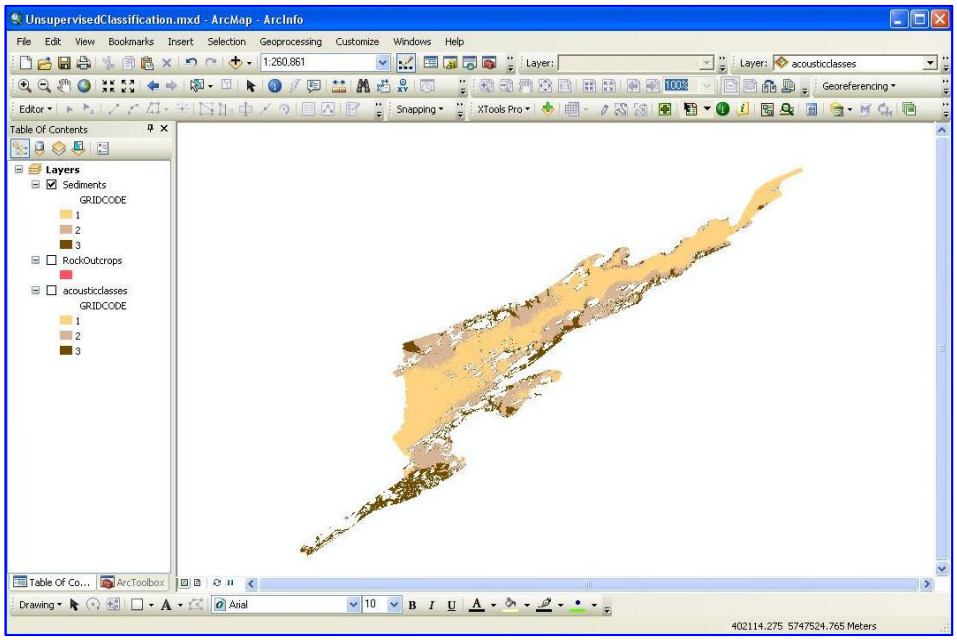
One solution to separate rock from coarse sediments is to overlay the traced rock outcrops from the shaded relief imagery and subtract (i.e. delete) the extent of the reefs from the file showing the acoustic classes. This will result in a clipped file that just displays sediments. This is a very simple task that can be easily done using the Erase tool in ArcToolbox. Open ArcMap and add the "AcousticClasses" and "RockOutcrops" shapefiles to a new map.



Click on the ArcToolbox icon and browse through the toolsets for the ***Erase*** tool (located in the following pathway: ArcToolbox\AnalysisTools\Overlay). Once the tool is highlighted a dialogue box opens requesting the user to specify the files required to perform the task.



Select the "AcouticClasses shapefile" from the Input Features dropdown list – this is the file which is to be clipped. Select the "RockOutcrops" file from the Erase Features dropdown list – the features of this file will be used to erase coincident features in the Input file. Give the output file a name, "Sediments.shp", and save it to the "SupervisedClassification" folder. Finally, click OK. The clipped file displaying the extent of sediments will appear on the map once processing is finished. Symbolise the data to display the 3 acoustic classes using the Layer Properties dialogue.



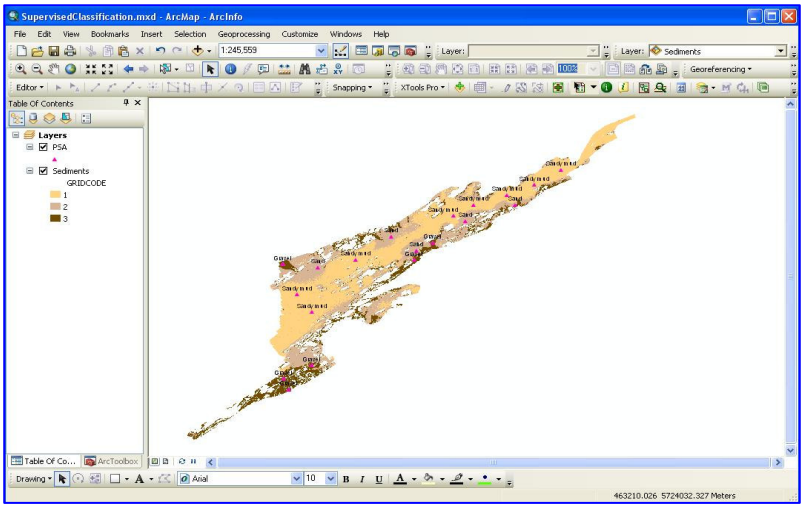
Supervised Classification

Supervised classification is the process of identifying areas on an image or a map using data from direct observations. The goal of classification is to assign each point in the study area to a class.

Groundtruthing Acoustic Classes

The most common method of identifying acoustic classes is to use information on sediments obtained from direct sampling of the area enclosed by the acoustic class. Sampling is usually undertaken during the course of the MBES survey, ideally the backscatter data is used to target the sampling effort in order to get representative samples from each of the acoustic classes provisionally identified. Once the sample data are acquired, they undergo Particle Size Analysis (PSA), the output of which is typically a point shapefile with Folk sediment classes assigned to each point. (Appendix 1 details how Folk classes are defined based on PSA of sample data).

In the following example, samples classed to Folk will be used to identify the acoustic classes. Add the "Sediments" shapefile, and the sample data shapefile, "Folk", to a new map.



The overlapping samples can be labelled using the "Folk" attribute. *(Go to the Layer Properties of the Folk shapefile and click on* ***Label Features*** *command, if the correct attribute is not selected as the label, then click on the Label tab in the Layer Properties and select "Folk" from the Label Field dropdown menu).*

The acoustic class attributes can now be updated to a sediment type (sandy, mud, sand and gravel) based on the sediments identified from the samples which overlap each of the 3 acoustic classes. *(The procedure for updating attibutes is outlined in detail in the Maximum Likelihood Classification section).*

Automated Classification

There are a number of softwares currently available offering a choice of methods for the production of thematic seafloor maps. MBES datasets can be processed using angular range analysis (using CARIS HIPS/SIPS Geocoder, and IVS Fledermaus Geocoder), and image based classification (using Quester Tangent QTC Swathview) in order to generate a variety of end products.

Comparing Different Interpretation Techniques

A bespoke comparison of interpretation methods was undertaken using the Kenmare dataset. The three software packages used to generate substrate maps included ESRI ArcGIS, QTC Swathview and Fledermaus Geocoder. Statistics on the difference between the extent of substrate classified by each technique were produced. In general, the similarity between the maps generated was relatively high, the main reason for the differences between the classifications were in the discrimination of sand from muddy sand, and the lack of any sand class in the results from Swathview. The results of all comparisons are presented in the following set of maps.

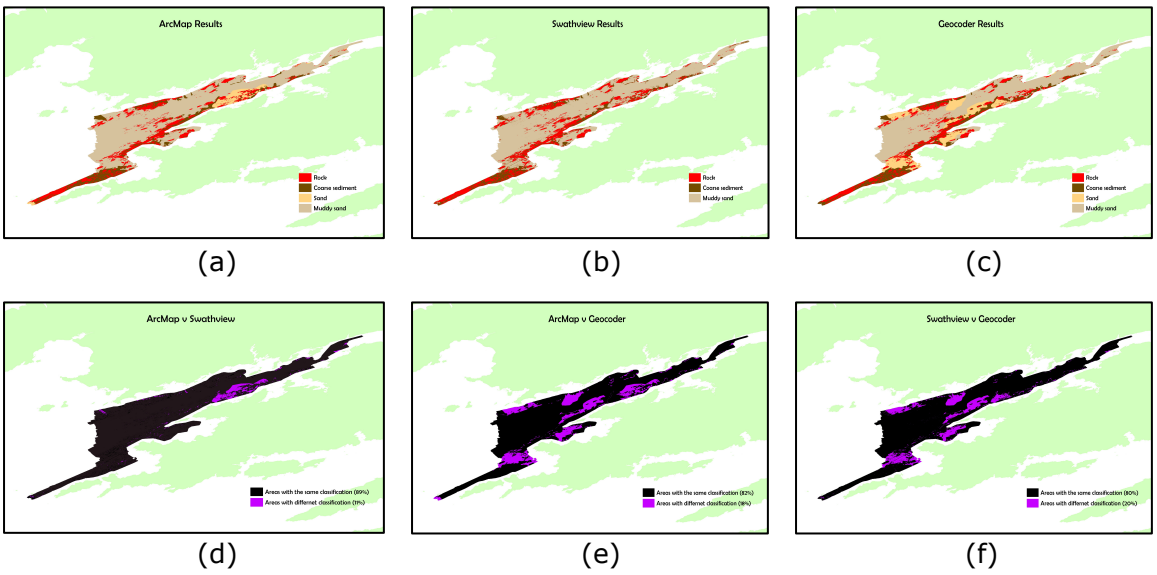


Fig. 11. Substrate maps generated from (a) ArcMap, (b) QTC Swathview and (c) Fledermaus Geocoder. (d) The results show an 89% similarity between the outputs from ArcMap and Swathview. (e) The degree of similarity between the results from ArcMap and Geocoder was 82%, and finally, (f) there was an eighty percent similarity between the substrate maps produced using Swathview and Geocoder.

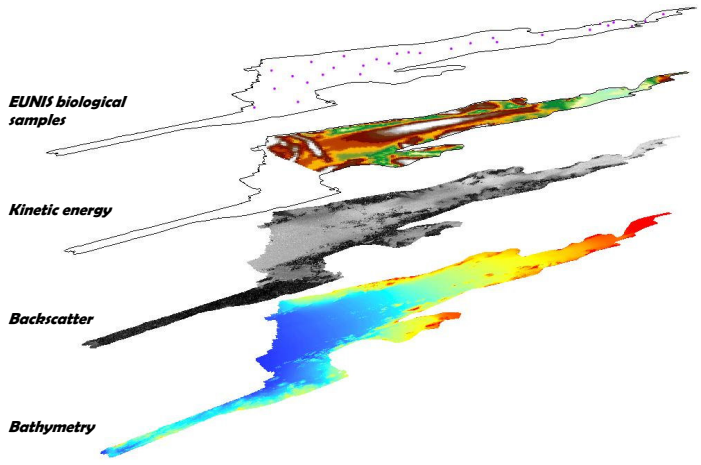
Maximum Likelihood Classification

Overview

Maximum Likelihood Classification is a multivariate tool that uses sample data to generate unique signature files from a band of rasters. Each signature contains multivariate statistics of each class identified. The entire area is classified, pixel by pixel, using this signature information so that in the end, all pixels are assigned to the class to which they most likely belong.

Process

In the following example, 3 raster layers containing information on the seabed in the form of depth, energy and substrate, along with biological samples, will be used in the supervised classification of the seabed into different EUNIS habitats.

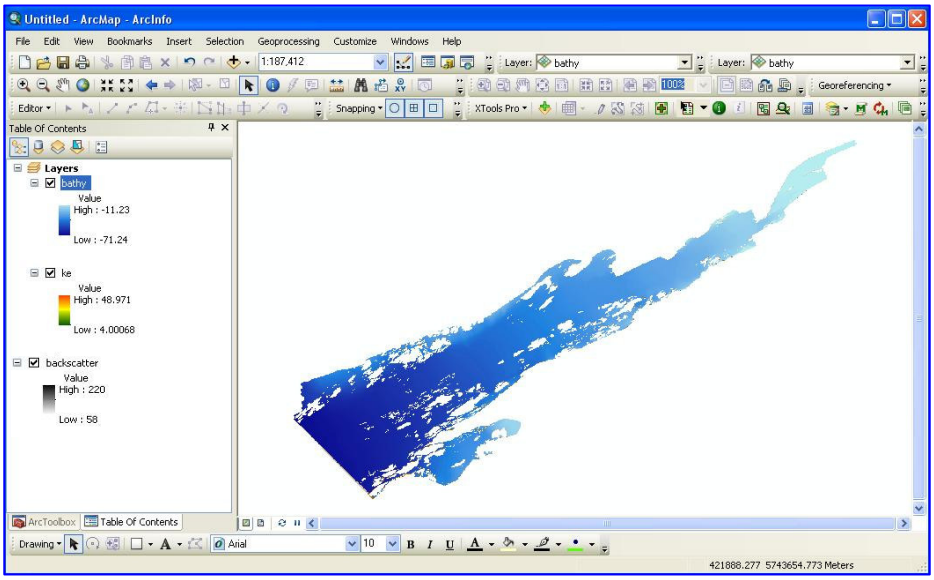


The following are the steps to perform a supervised classification:

1. Identify the input bands.
2. Produce training sites from known locations of desired classes.
3. Develop a signature file.
4. View and edit the signature file if necessary.
5. Run the classification.

Identify the input bands

Open ArcMap and add the rasters "bathy", "ke" and "backscatter" from the following pathway: C/ArcGIS/ClassData/SupervisedClassification/InputRasters. These rasters display information on bathymetry, kinetic energy and substrate hardness respectively.

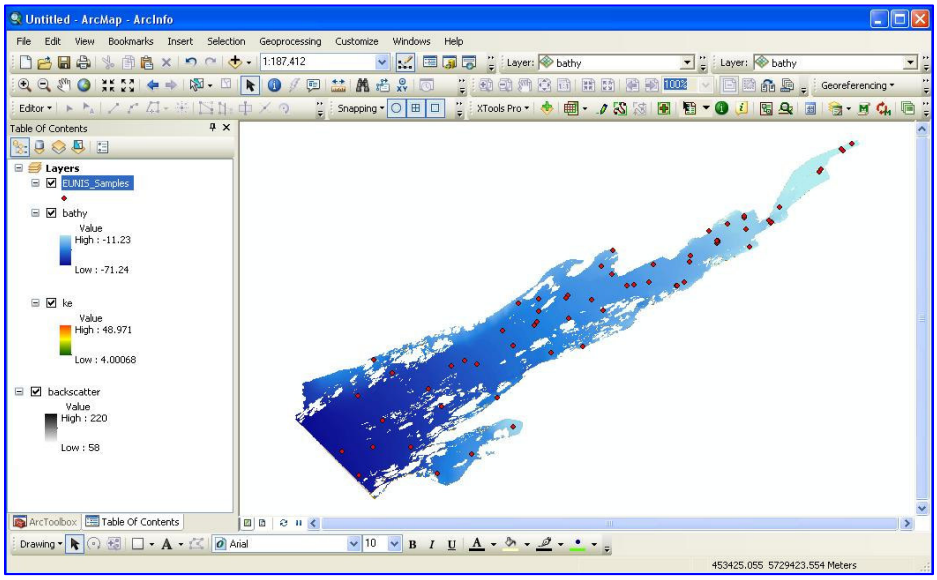


Multivariate analysis of these raster data at training sites (i.e. sample locations) will enable areas that cannot be groundtruthed to be identified. The rasters showing data on bathymetry, backscatter and kinetic energy will have a range of values unique to each class. It is this information that will be used to classify the entire study area into different EUNIS habitats.

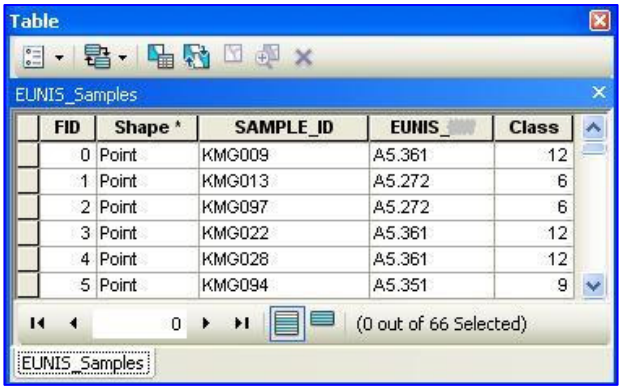
Note: *These raster data have been clipped to display pixel values for the areas covered by sediments only. This is done for each raster individually using the **"Extract by Mask"** command in the Spatial Analyst Tools in ArcToolbox (ArcToolbox\SpatialanalystTools\Extraction). Specify the input raster ("backscatter", "KinEnergy" or "bathymetry") and specify the "Sediments" shapefile as the Mask feature. Give the output clipped file a name and save to the "ClippedRasters" folder in the "SupervisedClassification" folder.*

Produce Training Sites

There are 2 approaches to generating the training sites. The user can buffer existing sample data which has been classified into unique classes or the Training Sample Manager (located on the Image Classification Toolbar) can be used. In this instance, the former approach will be described. Add the shapefile, "EUNIS_Samples", from the following pathway: C/ArcGIS/ClassData/SupervisedClassification/SampleData.



The point sample data must be converted into a polygon file in order to develop the signature file that will be used to classify the entire area. Buffering the sample data will result in a polygon file. A polygon will enable more pixel values from the underlying rasters to be analysed at the signature generation stage of the classification process. Before buffering the point data, the attributes of the file need to be examined to ensure that the attribute field containing the class values (unique to each class type present) will be included in the buffered, polygon output file.

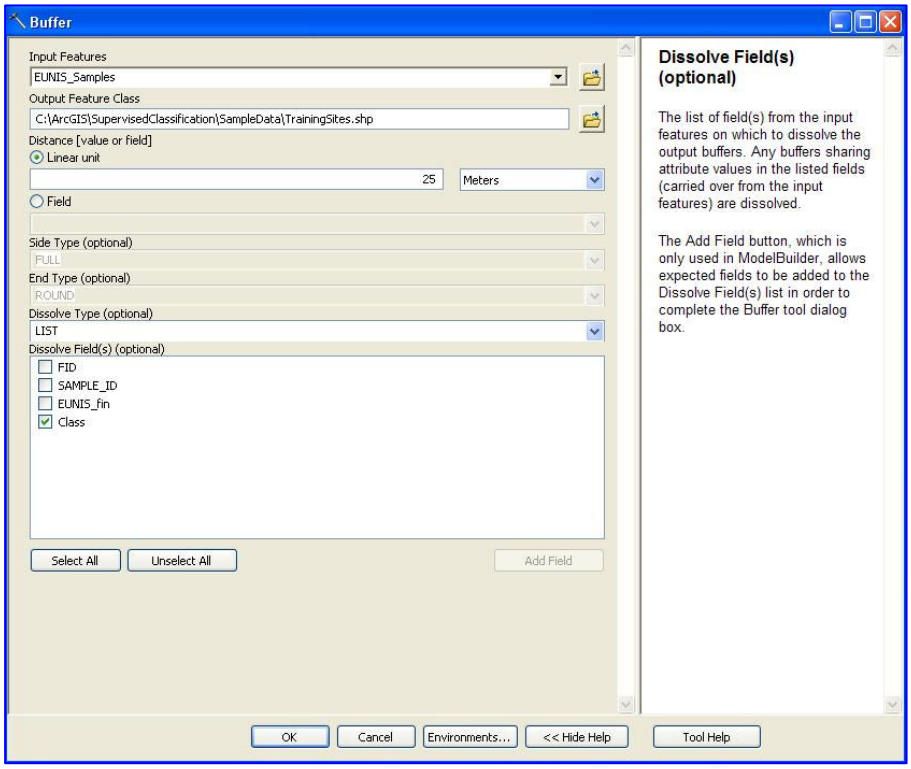


FID	Shape *	SAMPLE_ID	EUNIS_	Class
0	Point	KMG009	A5.361	12
1	Point	KMG013	A5.272	6
2	Point	KMG097	A5.272	6
3	Point	KMG022	A5.361	12
4	Point	KMG028	A5.361	12
5	Point	KMG094	A5.351	9

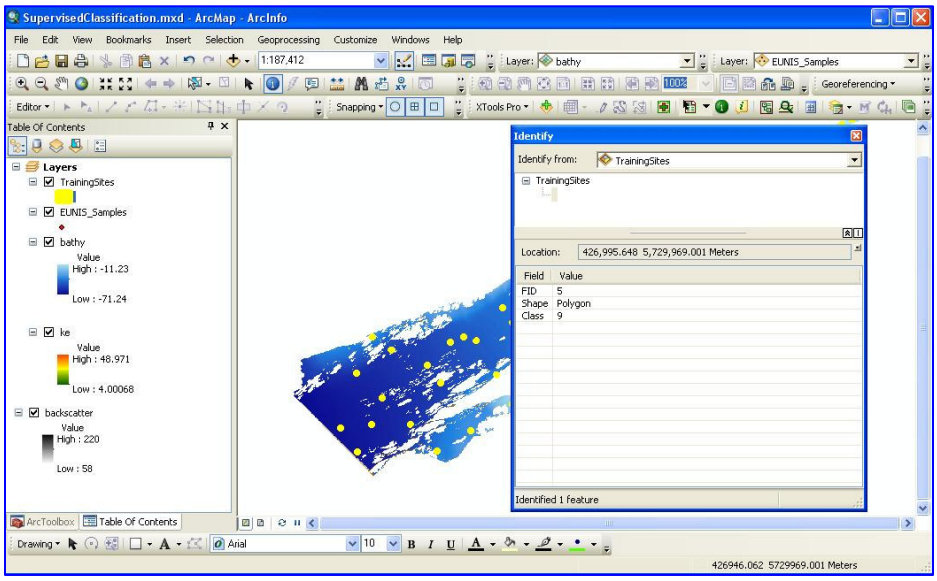
In this example, the attribute field which needs to be included in the buffered file is the field entitled *"Class"*. Each value in this field corresponds to a unique, EUNIS class identified in the samples. This field has to be in short integer format.

Buffering

Considering the pixel size of the input imagery is 5m, a buffer of 25m was used in order to select a sufficient number of pixels that could uniquely describe the class but which were not too far from the sample location. To buffer the point sample data, click on the Buffer tool from ArcToolbox or from the dropdown Geoprocessing Menu (located on the Main Menu). Select the EUNIS Sample point file, "EUNIS_Samples" as the input data, give the output file a name, "TrainingSites", specify a buffer distance of 25m and finally, dissolve the fields based on the class attribute (see dialog box below).

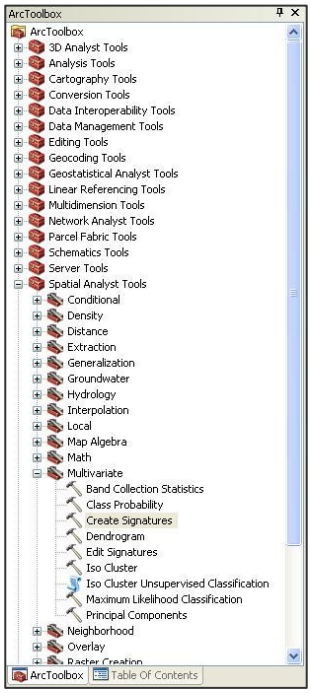


A polygon file will now display in ArcMap displaying a 25m buffer around each sample point file. Each polygon will have a class value associated with it. Use the Identify tool  to check the class value associated with each polygon.

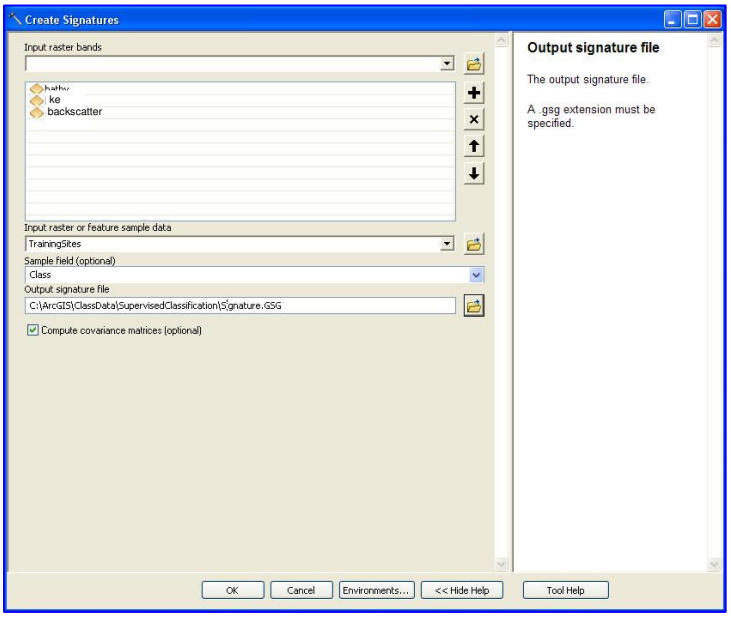


Develop a Signature File

The next step involves using ArcToolbox Multivariate Tools to firstly generate a signature file and then, to use this file in conjunction with the raster data to classify the entire survey area. To generate the signature file, select the ***Create Signature*** tool in ArcToolbox at the following address: SpatialAnalystTools\Multivariate.



A dialog box appears requesting the name of the input rasters and training site and the final output signature file. Select the rasters "bathy", "ke" and "backscatter" from the dropdown list as the Input Raster Bands. Select "TrainingSites.shp" as the Feature Sample Data and call the output file, "Signature".



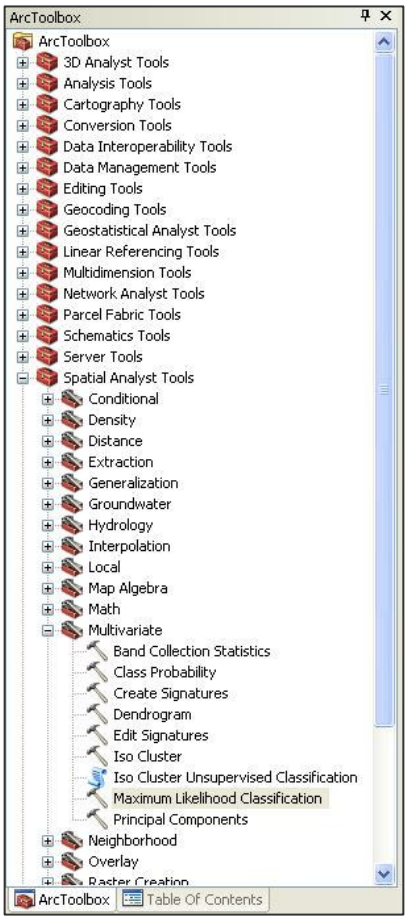
The output signature file is a .GSG which can be opened and examined in Textpad. Each class can be distinguished now by its statistical characteristics.

signature2.gsg

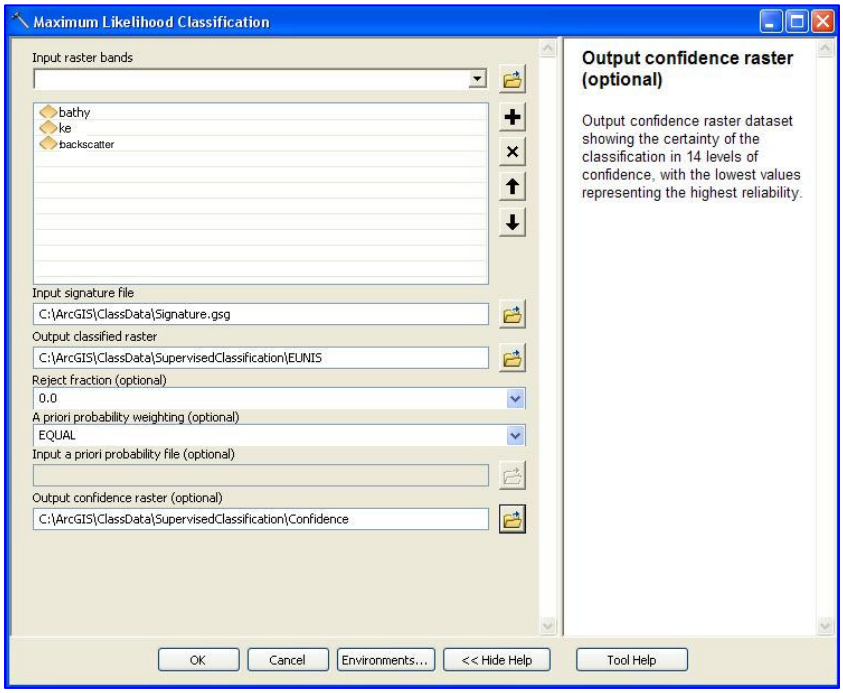
```
# Signatures Produced by ClassSig from
#    Class-Grid __1000001
#    and Stack __1000000

#    Number of selected grids
/*          3
#    Layer-Number    Band-name
/*          1       ke5m_clip\ke_5m_clip
/*          2       bathy5m_clip.tif\Band_1
/*          3       bs_b1_clip\bs_b1_clip

#  Type   Number of Classes   Number of Layers    Number of Parametric Layers
    1            8                 3                        3
# ================================================================

#  Class ID     Number of Cells    Class Name
      1              397
# Layers            1             2             3
# Means
                 10.62558      -38.75526      156.09068
# Covariance
    1             55.00911      -42.23061       19.60150
    2            -42.23061       82.81185       21.69341
    3             19.60150       21.69341       99.80489
# ----------------------------------------------------------------

#  Class ID     Number of Cells    Class Name
      5              316
# Layers            1             2             3
# Means
                 16.66441      -39.95804      126.06329
# Covariance
    1             46.90594      -28.57844        5.20064
    2            -28.57844       47.77745      -19.62152
    3              5.20064      -19.62152       25.13884
# ----------------------------------------------------------------

#  Class ID     Number of Cells    Class Name
      6              470
# Layers            1             2             3
# Means
                 18.15006      -51.88930      123.09787
# Covariance
    1             22.59447       22.72121       -5.13034
    2             22.72121       80.50502      -49.41162
    3             -5.13034      -49.41162       48.90298
# ----------------------------------------------------------------
```

Run the Classification

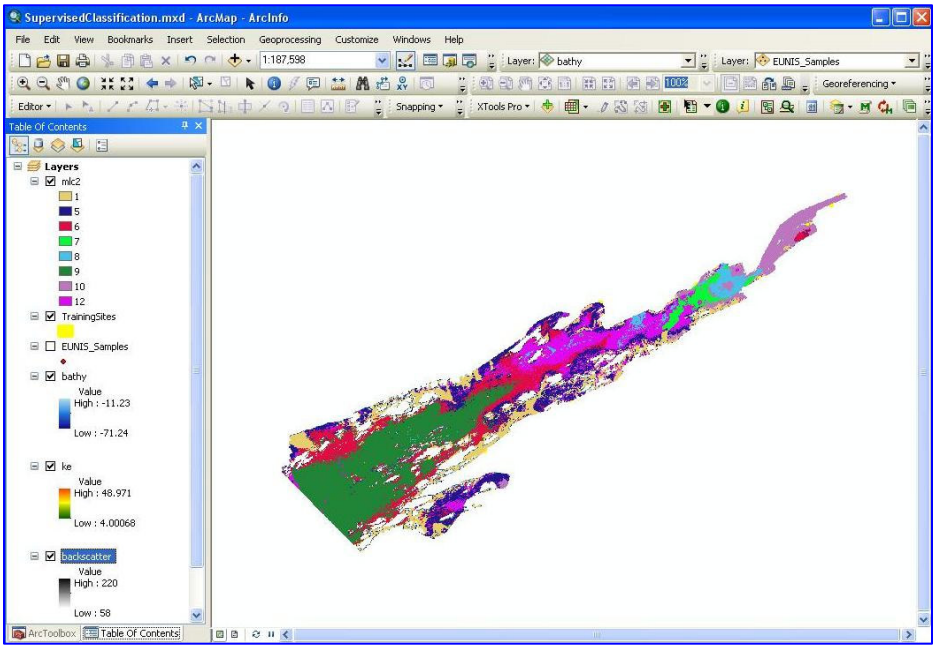
The final step in the classification process is to use the statistical characteristics of each class generated in previous step to classify the whole area. In order to do this both the input rasters and the signature file containing the statistical characteristics of each class will be used by the Maximum Likelihood Classification Tool to generate a final raster displaying EUNIS habitats. The MLC tool is located at the following address: ArcToolbox\SpatialAnalystTools\Multivariate.



A dialog box appears requesting the name of the input rasters, the signature file and the final output raster. Select the rasters "bathy", "ke" and "sed" from the dropdown list as the Input Raster Bands. Select "Signature.GSG" as the Input Signature File and call the Output Classified Raster, "EUNIS". Finally, indicate that a confidence assessment of the classification is generated by specifying a name and known address for the Output Confidence Raster. Click OK.



The MLC tool predicts the distribution of EUNIS classes in the area using information on the statistical characteristics of raster data at groundtruthed locations. The result of the entire process is a raster displaying EUNIS habitats on soft sediments.

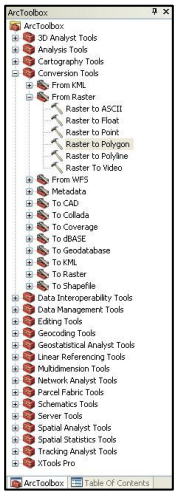


Final Edits

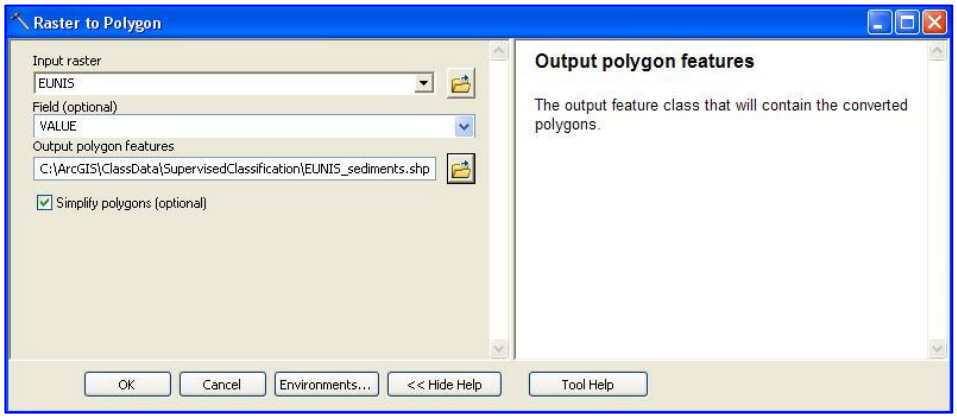
Converting from raster to polygon

The EUNIS habitats are currently classed as an integer in the attributes, the next step involves updating the attributes of this layer with a EUNIS code and a EUNIS habitat class. (Part of the process in the generation of signature files involved simplifying the standard EUNIS codes into integers. This was done because the MLC process requires classes in the signature file to be in integer format).

Before the EUNIS layer can be updated, it must be converted from a raster dataset into a polygon shapefile. In ArcTools, select the "Raster to Polygon" tool.



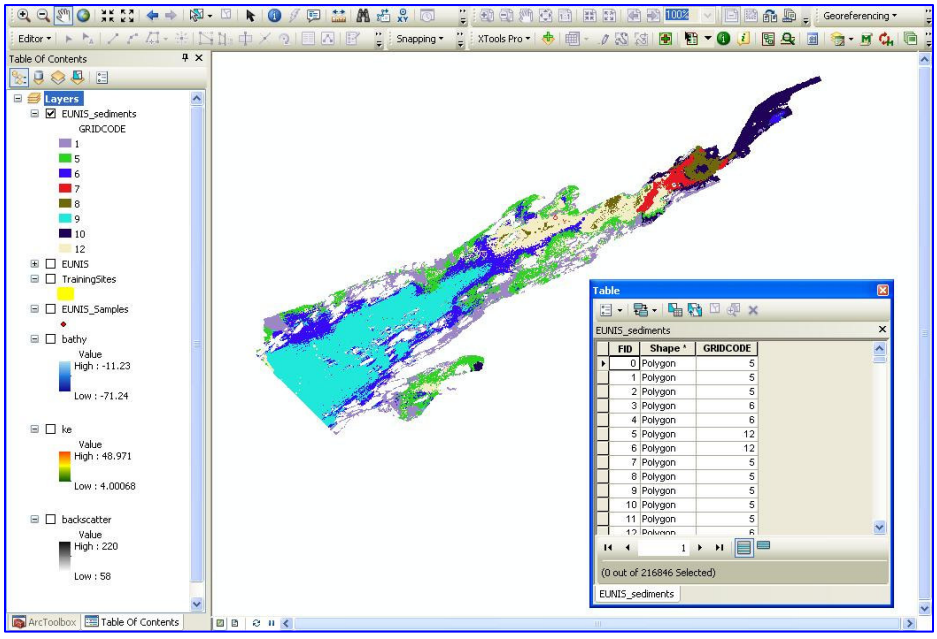
A dialog box opens requiring the user to identify the input raster and to provide a name and location for the output shapefile. Select the "EUNIS" layer as the input raster and call the output file "EUNIS_sediments.shp" (save the shapefile to the following address C\ArcGIS\ClassData\SupervisedClassification).



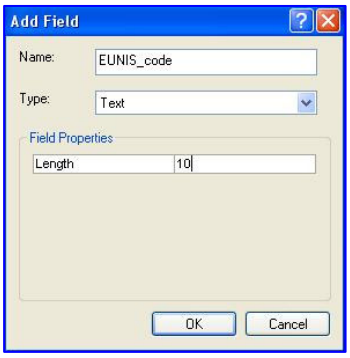
The resulting shapefile displays the exact same information as the raster data. The advantages of having these data in shapefile format is that vector files are generally easier to edit and the data can now be merged with other vector files such as the reef data traced from the shaded relief data.

Updating Attributes

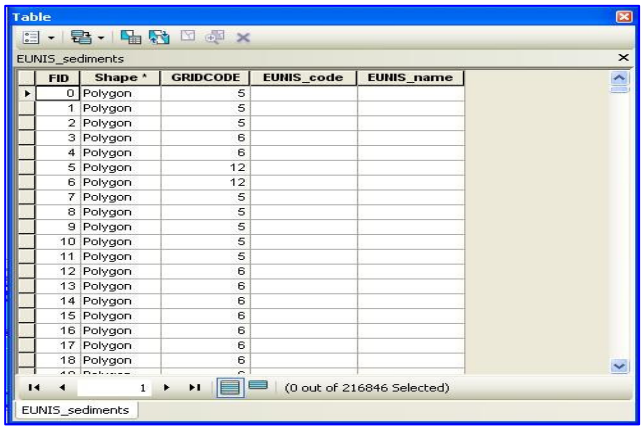
Open the attribute table of the newly generated shapefile, "EUNIS_sediments". The attribute called "Gridcode" contains a series of integers which are all code for a unique EUNIS class. These codes must now be updated with the proper EUNIS code and the associated EUNIS description. To do this, 2 new fields must be added and then the attributes can be filled in.



To add a new field, click the dropdown arrow on the top left of the attribute table and select the ***"Add Field"*** option. A new dialog opens and requests information about format of the new attribute field.

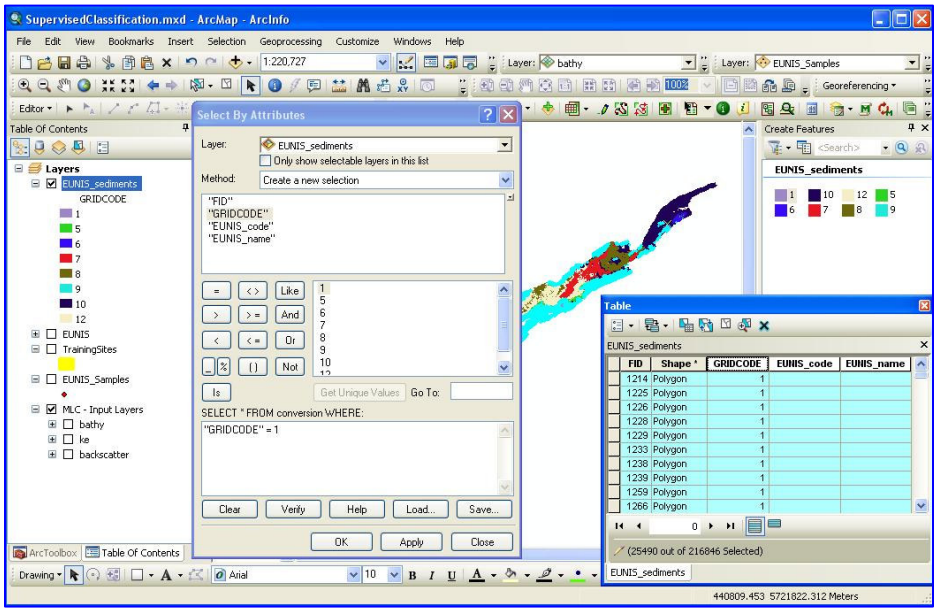


Create 2 new fields, call the first new field "EUNIS_code", assign a text format to it with a character length of 10. Call the second field, "EUNIS_name", assign a text format to it and give it a character length of 100 (the names of some EUNIS classes are quite long).

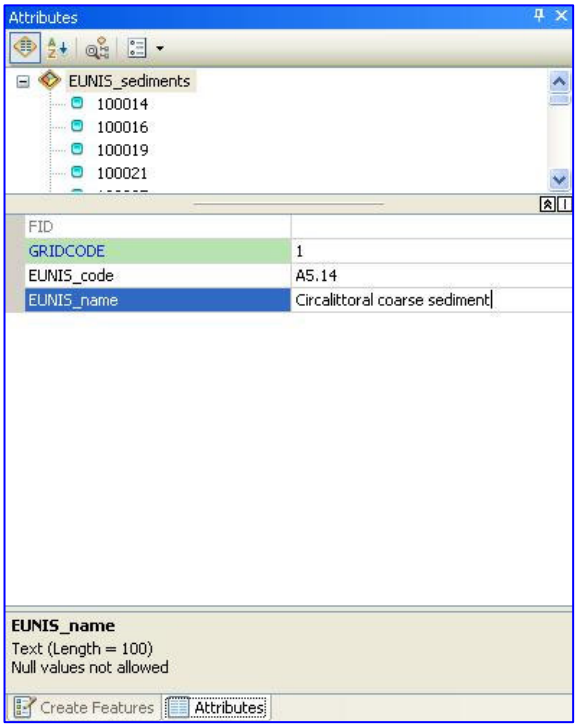


Next begin filling in the attribute information for both fields. To do this, start an editing session by clicking the ***Editor-Start Editing*** command from the Editor toolbar dropdown menu in ArcMap. Select the "EUNIS_sediments" shapefile as the shapefile you wish to edit.

Next select all attributes with a gridcode value of 1. The fastest way to do this selection is to use the ***Selection - Select By Attribute*** command located in the Main Menu in ArcMap.



To update several attributes at the same time, click the Attribute icon on the Editor toolbar and click on the name of the shapefile that is being edited on the Attributes Tab (right-hand side of the screen). Next, type *"A5.14"* into the EUNIS_code field on the Attributes tab and hit Enter. Define the EUNIS_name as "*Circlittoral Coarse Sediment"* and also hit Enter.



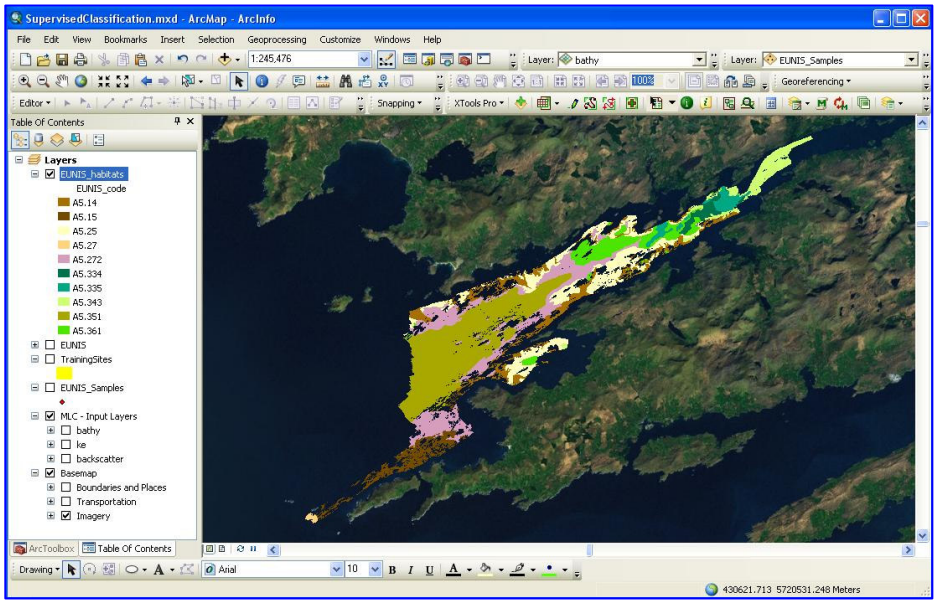
Next select all attributes with a gridcode value of 5 and update the EUNIS_code and EUNIS_name fields using the same method. When all the attributes have been updated, click Save Edits from the Editor Toolbar dropdown. To end the editing session, click on the Stop Editing command from the Editor toolbar dropdown menu.

The following list shows which EUNIS classes are represented by integers.

1	-	A5.14
5	-	A5.25
6	-	A5.272
7	-	A5.334
8	-	A5.335
9	-	A5.351
10	-	A5.343
12	-	A5.361

(The complete list of EUNIS habitats are available on the JNCC website: http://jncc.defra.gov.uk/pdf/EUNIS_Correlation_2007-11_20101206v2.pdf).

The final updated shapefile can now be symbolised by EUNIS code or the name of the EUNIS habitat.



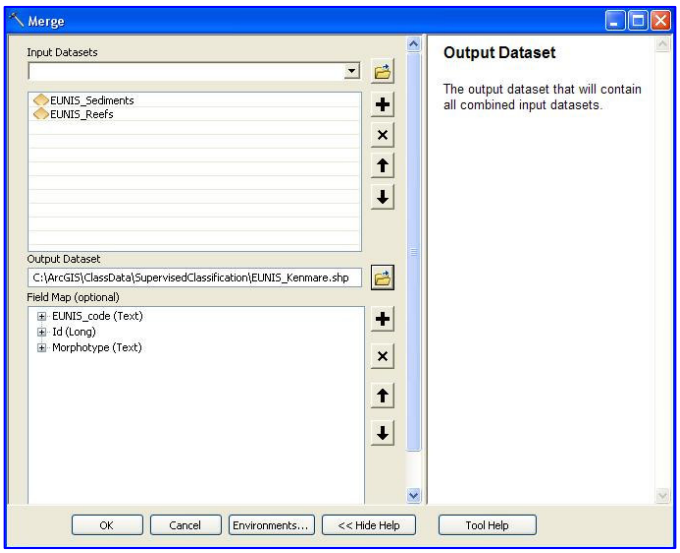
Repeat the entire MLC procedure to classify the Rock Outcrops into EUNIS classes. This time the 3 input raster layers will be the clipped bathymetry, clipped KE and clipped backscatter rasters (the original rasters displaying bathymetry, backscatter and Kinetic Energy will need to be clipped by the "RockOutcrops" shapefile. (This is done for each raster individually using the **"Extract by Mask"** command in the Spatial Analyst Tools in ArcToolbox). The signature file required to run the MLC tool is generated from classified video drop data in point format which has been buffered and reformatted (EUNIS code has been simplified to an integer in order for the MLC to work).

When the rock outcrop raster data have been classified, it must again be converted to a vector polygon file and its attributes must be updated with standard EUNIS data. The classified EUNIS rock outcrops can then be displayed in ArcMap.

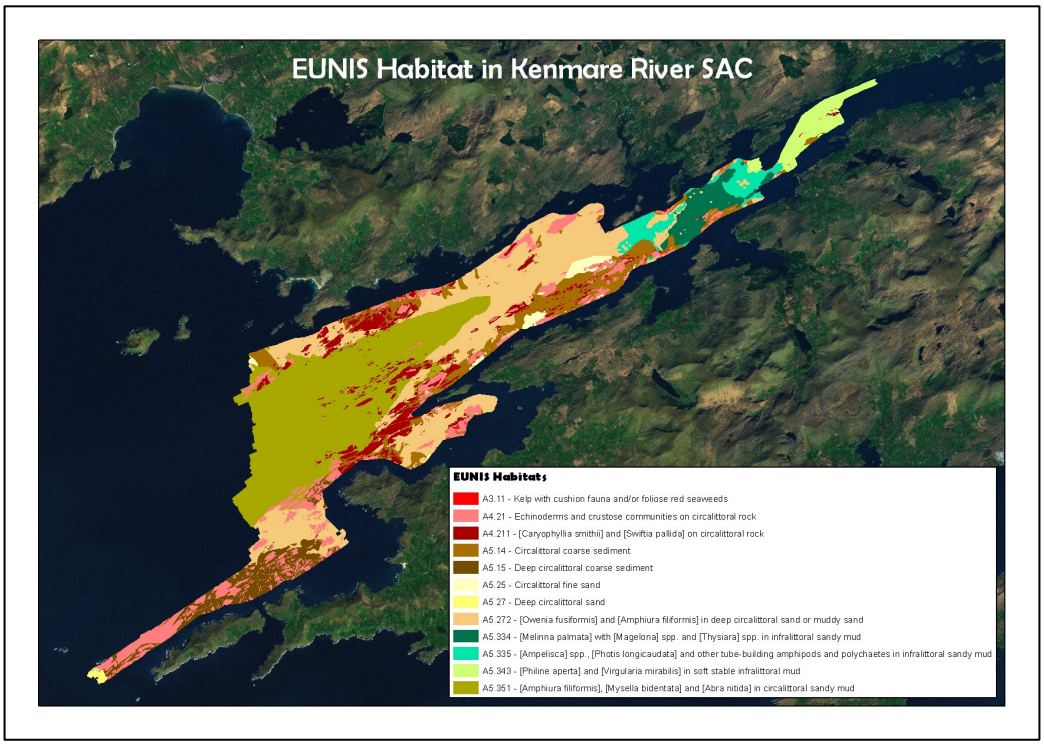
Since both the classified rock outcrop and sediment data are in vector format, have the same attributes and are part of the same map, it makes sense to merge both polygon files into one final EUNIS Habitat shapefile for Kenmare.

Merging Shapefiles

To do this, click on the Merge tool from the Geoprocessing Menu on the Main Menu in ArcMap. Select the "EUNIS_Sediments.shp" and the "EUNIS_Reefs.shp" as the Input Datasets, give the output dataset a name "EUNIS_Kenmare.shp" and a location (C\ArcGIS\ClassData\SupervisedClassification), and then click OK.



This merged file is the final EUNIS habitat map for Kenmare and can now be displayed in ArcMap. Symbolise the shapefile using the EUNIS name attribute and view the map in Layout mode with a legend naming each EUNIS habitat.



Appendix 1 – Folk Classification and Modified Folk Classification

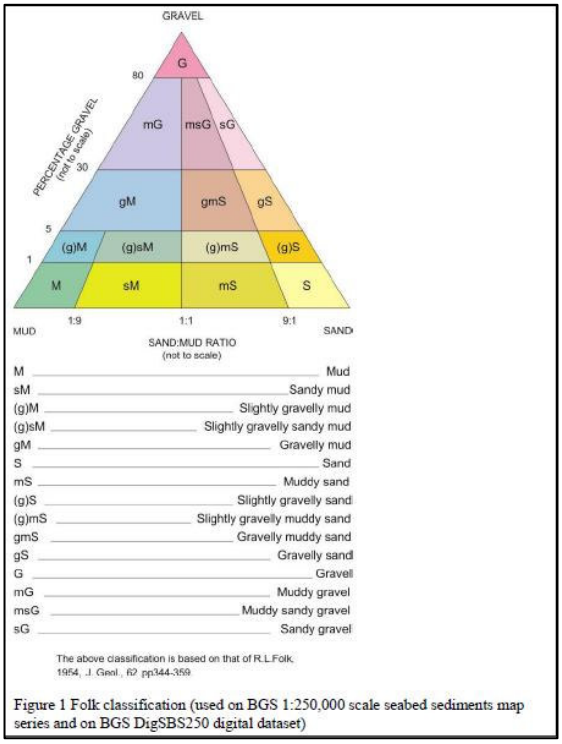
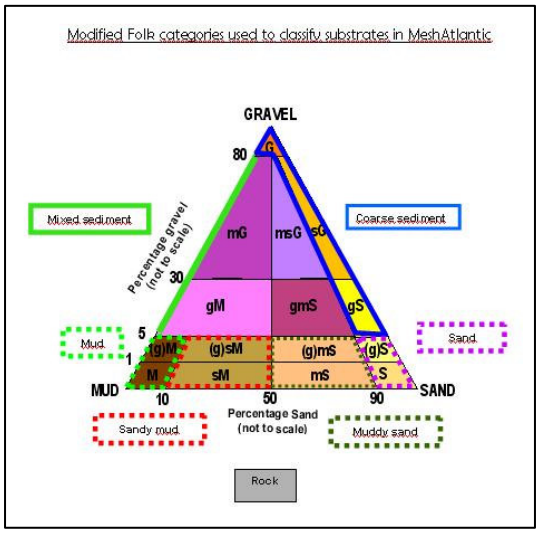


Figure 1 Folk classification (used on BGS 1:250,000 scale seabed sediments map series and on BGS DigSBS250 digital dataset)

Folk Classification of sediment samples.



Modified Folk classification used in MeshAtlantic project.