Investigating sea bird abundance in the British Isles using GIS

Scenario:

In this scenario, we will undertake an initial exploration of factors affecting sea bird abundance in the British Isles. In an environmental management context, often an investigation of species habitat involves looking both at factors that can be influenced by management practices and others that cannot. In this scenario, we wish to unravel the possible contributions of fishing practices and coastal land use in determining sea bird numbers, so we can plan an appropriate conservation strategy accordingly. As a first step, before looking at these aspects of sea bird habitat, both of which can be influenced by management, we will look at sea depth and its possible influence on counts of one particular seabird species, the fulmar. Evidence from Canada (see paper by Huttman and Lock, 1997) suggests that fulmar abundance is influenced by sea depth. But is this true in the UK? Before moving on and adding in further variables, some of which can be controlled via environmental management (e.g. fishing regimes; coastal land cover), we will first explore whether fulmar counts are related to sea depth, as they are reported to be in Canada.

In this exercise, we will use some tools within ArcView to explore the habitat preferences of sea birds. However, bear in mind that there are now many other software tools for carrying out this kind of analysis and the tools within ArcView really offer just a first step to carrying out more sophisticated analysis.

Data:

We will make use of the following data for this exercise:

- Abundance data for coastal and some inland sites around the British Isles are available for approximately 25 species from the sea bird census 2000, for which fieldwork took place during 1999-2003.
- Etopo1 global digital elevation model, incorporating both land topography and bathymetric data. Data have already been downloaded and cropped to cover only Ireland and the UK, rather than the world (to reduce download times for this exercise).

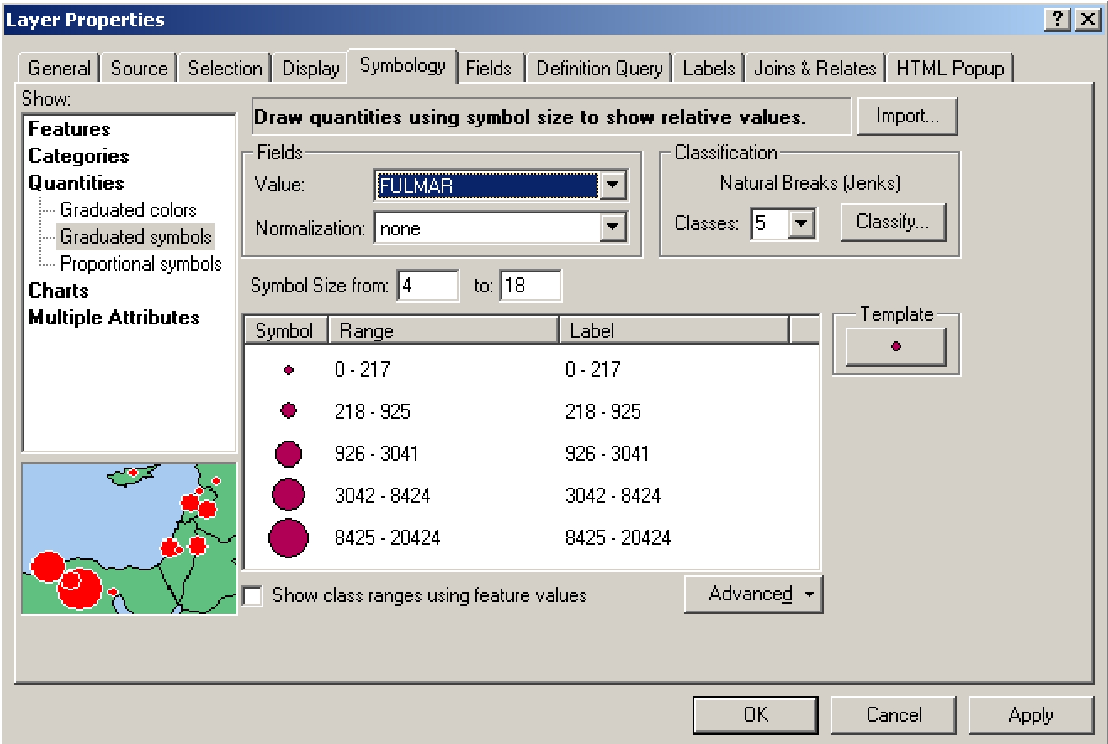
Instructions:

Download and prepare the seabird abundance data set from the MAGIC data portal:

- Point your web browser to http://www.magic.gov.uk/ to start downloading the seabird abundance data from the 2000 seabird census
- select 'data set info and download' from top panel on screen
- select dataset = 'seabird nesting counts (British Isles)' and select 'go'
- quickly read the meta-data about this data set
- select 'new user' at top of screen, then follow the instructions on creating a new account
- Once you have created your new account, press the button marked 'download'
- enter in the final date of course for 'until when will data be used'
- under 'how will the data be used?', enter in 'As part of GIS practical exercise for a university degree programme'
- under 'available format', select **shape file**
- check that you agree to the terms and conditions at the foot of the screen, and select 'submit'

Once you have downloaded the data, unzip the files and place them together in the same folder, then open up the shape file from within ArcMap (via *file…add data*).

Next, shade in the fulmar abundance data by right-clicking on your new **magseabirds** shape file and selecting *properties*, then the *symbology* tab Select *quantitites…graduated symbols* and under *fields*, select **fulmar.**



You should now see a map displaying fulmar counts around the British Isles – the larger the circle, the greater the number of fulmars observed at each location.

1. What do you notice about the spatial distribution of fulmars (turn to the end of the exercise for answer)

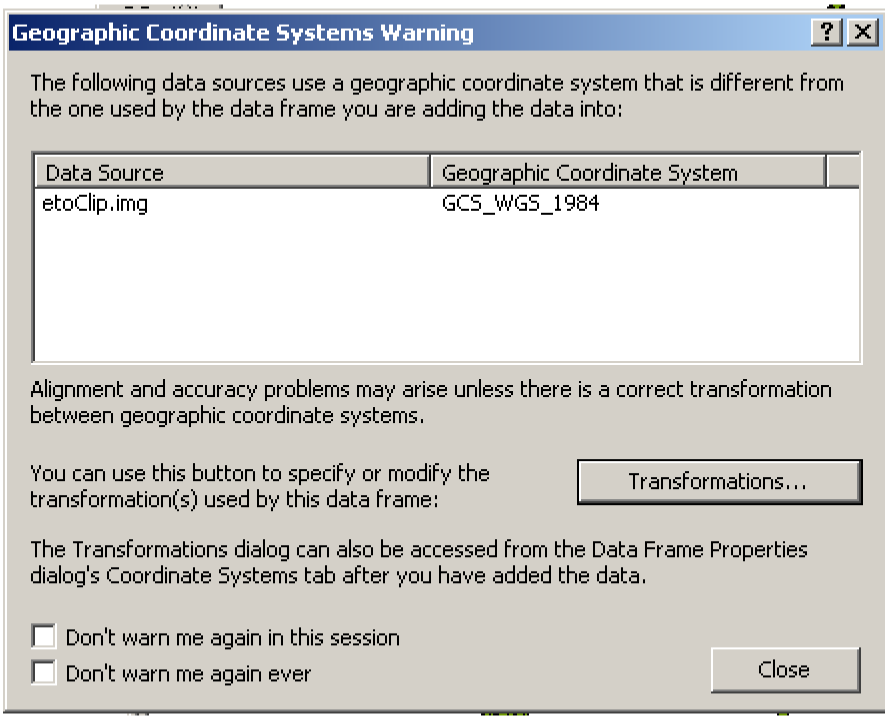
Because this will be useful later, we also need to add in a new field that will contain a unique identifier number for each point in the data file we have downloaded, to do this:

- right-click on the **magseabirds** layer and choose *open attribute table*
- click on the *options* button at the foot of the screen and select *add field…*
- Create a new field of type **long integer** called **uniqueid**
- Right-click on the final column header in your table of data (where the text 'uniqueid' appears immediately above your rows of data). Select *field calculator* and then click on 'yes' when asked whether you wish to perform a calculation outside of an edit session.
- Under *fields*, double-click on **fid** so that it appears in the box at the foot of this dialog box (where it says *[uniqueid] =*) and click on OK.
- FID contains a unique internal feature ID number for each point. The steps here take this internal feature number and copy it over into the new **uniqueid** field that you have just created.
- Click on OK to add the unique numbers to your point file

Prepare the sea depth data:

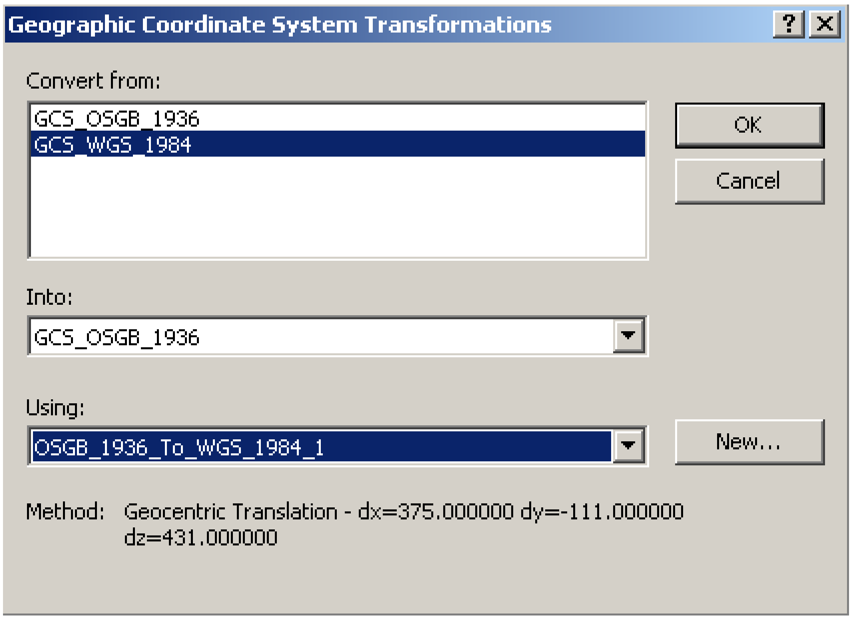
Unzip the **Etopoclip** raster grid and add this to your map display using *file…add data*.

When you open the raster data set up, you may well see a warning message:



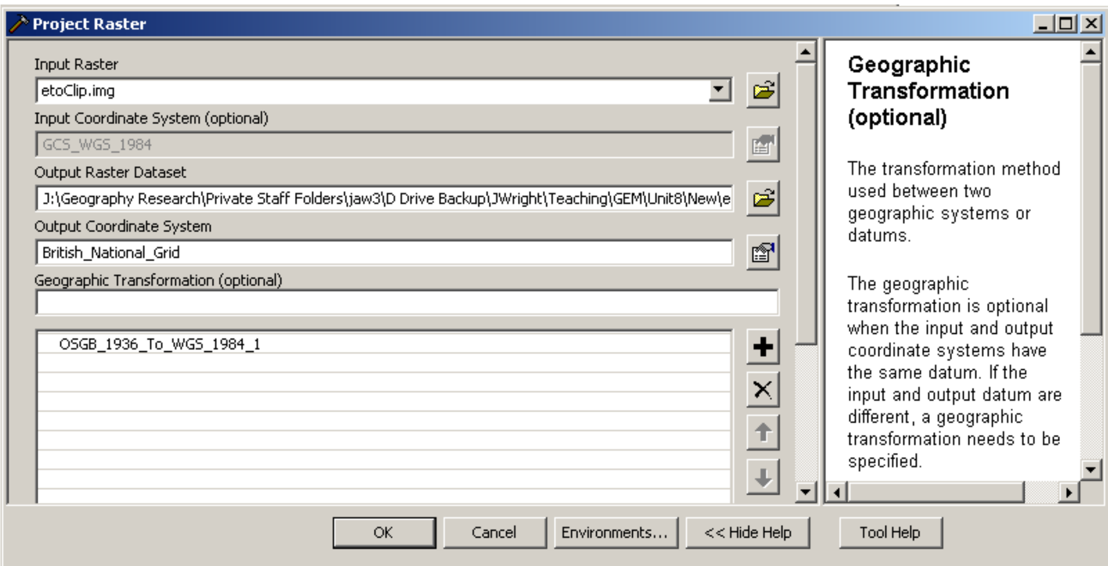
2. Why do you think you get this warning message? (turn to the end of the exercise for answer)

We can temporarily fix this problem by selecting the *transformations* button and choosing to convert the datum for our raster grid from GCS_WGS_1984 to GCS_OSGB_1936, using the OSGB_1936_To_WGS_1984_1 option (note that this is a best fit transformation for the whole of the British Isles, so probably the best option given our study area), as shown below.



If we hit OK, this will ensure that the two map layers are displayed correctly, relative to one another, without changing the underlying raster map layer stored on disk. However, we can make a new version of our raster grid, which is stored permanently on disk in British National Grid Coordinates instead of latitude and longitude. This is useful for the purposes of running commands in the ArcToolBox, which will often make use of a map layer's coordinate system. Since we will use some ArcToolBox commands later, we will change the raster's co-ordinate system now:

- In the ArcToolBox, select *data management / projections and transformations / project raster*.
- Select **Etoclip** as the *input raster* and enter in an appropriate output file name
- Next to Output Coordinate System, select *projected coordinate systems / national grids / British National Grid*
- Next to *geographic transformation*, select OSGB_1936_TO_WGS_1984_1 – this is a transformation appropriate for the whole of the British Isles.
- Click on OK and ArcView should convert the elevation / bathymetry raster grid from latitude & longitude to British National Grid co-ordinates.



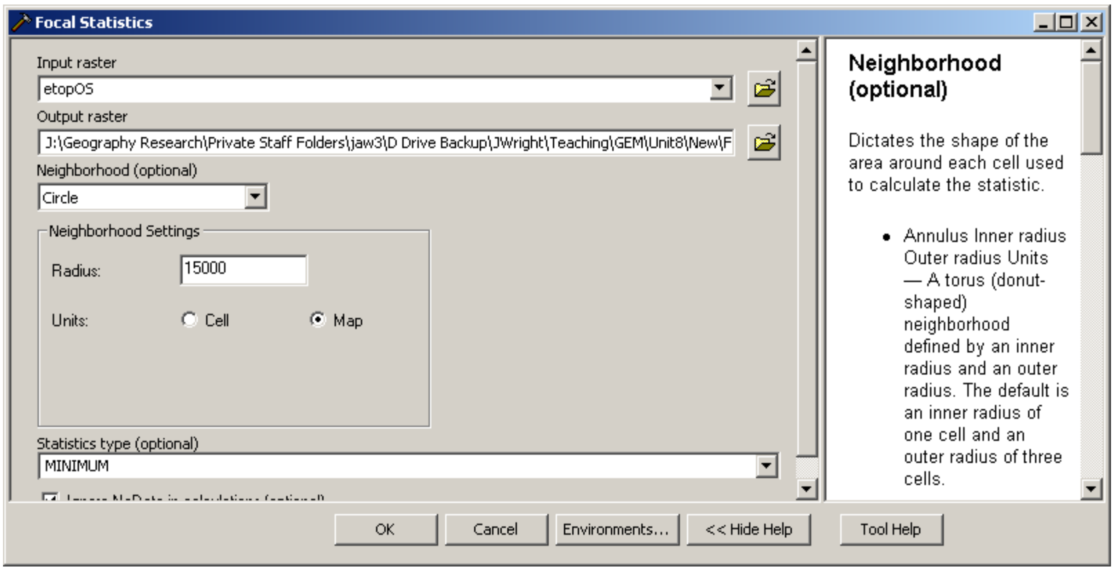
Generate a sea depth variable

We now have our bathymetry / elevation data and sea bird data in the same coordinate system. However, we are really interested in capturing the characteristics of the sea area over which the fulmars are foraging, not the characteristic of the nest site itself. To find out about the broader environment around each nest site, we can use a neighbourhood operation, which will summarise the characteristics of groups of grid cells neighbouring each point in our study area:

- Within the ArcToolbox, under *spatial analyst / neighbourhood,* select *focal statistics*.
- Select your elevation / bathymetry grid in British National Grid format as the input raster and enter a suitable name for your output raster, e.g. **minelev**
- It seems logical to choose a **circle** for the *neighbourhood*, given that with this operation, we want to represent the foraging habits of a fulmar operating from a coastal nest site (the area the fulmar is foraging over is likely to be circular, not rectangular, say)
- Select **Map** as the *Units* for the *neighbourhood settings*. This is where having data projected in metres on the British National Grid proves useful. Our Map units are now metres and for this reason, it is easier to work in map units rather than in grid cells, because we can think about what the distances we use represent on the ground. With detailed ecological data on the foraging habits of fulmar, we could enter in a range here that represented the radius of the typical foraging behaviour of the sea bird. For our purposes we will enter **15000** for the *radius*, assuming that the fulmar typically forages up to 15km from its nest site.
- Select **minimum** as the *statistics type*, on the grounds that we wish to identify offshore areas of greater sea depth (for coastal sites, the

minimum will be in the sea, and not influenced by onshore elevation values)

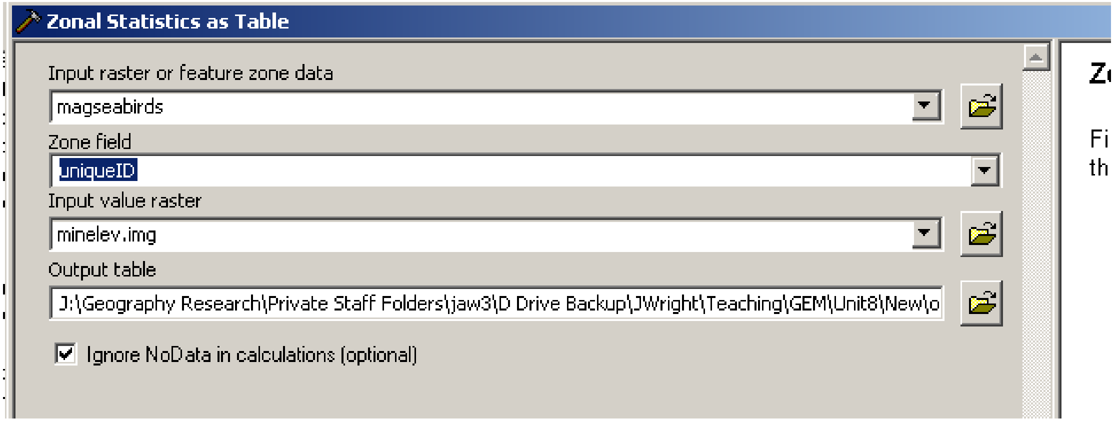
- Choose OK to generate a new raster that replaces each grid square with the minimum elevation (on land or sea) within 15km of that grid square.



Calculate sea depth for each bird census point

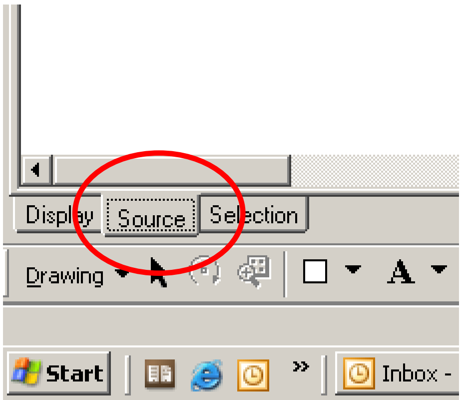
We now need to extract sea depth information for each of the points in our data file automatically. Earlier, we created a new field called **uniqueid**, which contains a unique number for each point we are working with and helps us to keep track of which point is which during this process. We will make use of that field now:

- Again within the ArcToolBox, under *spatial analyst / zonal*, select the command *zonal statistics as table*.
- As the *Input raster or feature zone data*, select your sea birds point layer
- For the *Zone field*, select the **uniqueid** field that you created earlier.
- For the *Input value raster,* select the raster grid generated by the focal statistics routine earlier.
- Choose a suitable name for the *Output table* that will be created.



When you click OK, the software will create a new table (not a map layer), which contains the uniqueid value for each point, along with the minimum elevation value within 15km of that point.

Note only for those using ArcGIS version 9.3 or earlier: Because the output is not in map format, you need to click on the *source* tab at the bottom left of the ArcMap screen to see it:



Right-click on your output table and choose *open* to look at the output.

Attributes of out

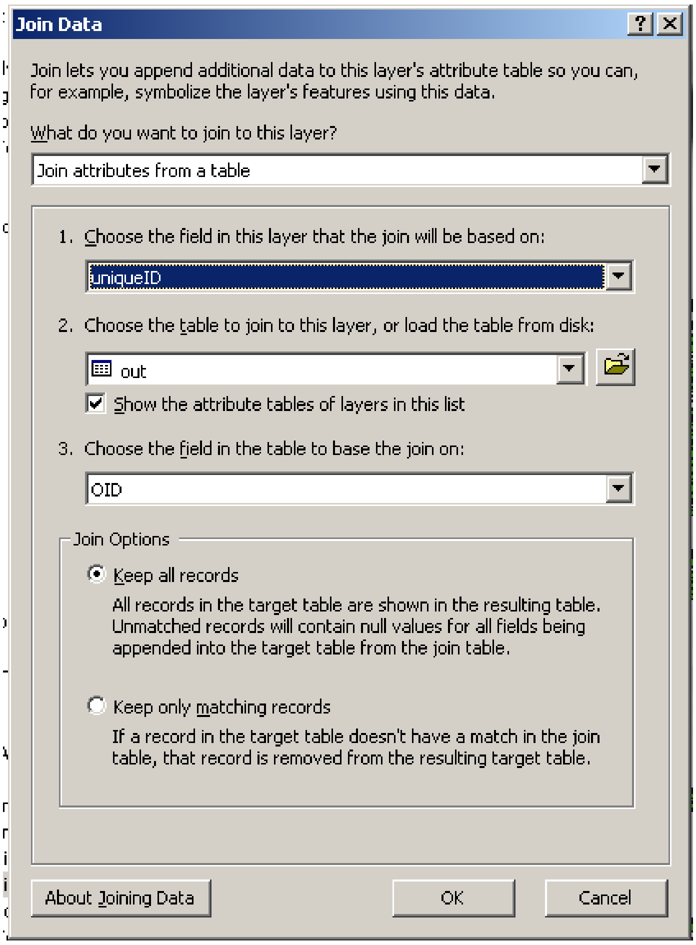
OID	VALUE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
0	0	1	2351710	-33	-33	0	-33	0	-33
1	1	1	2351710	-33	-33	0	-33	0	-33
2	2	1	2351710	-46	-46	0	-46	0	-46
3	3	1	2351710	-59	-59	0	-59	0	-59
4	5	1	2351710	-70	-70	0	-70	0	-70
5	7	1	2351710	-70	-70	0	-70	0	-70
6	10	1	2351710	-68	-68	0	-68	0	-68
7	12	1	2351710	-67	-67	0	-67	0	-67
8	13	1	2351710	-68	-68	0	-68	0	-68
9	14	1	2351710	-62	-62	0	-62	0	-62
10	15	1	2351710	-64	-64	0	-64	0	-64

Each row represents a different point in the sea bird census file and the ID numbers in the value / count fields match those that you created in the

uniqueid field earlier. The *zonal statistics* command has summarised all of the grid cell values for each point. Since these are points and not areas, each point only covers a single grid cell (therefore the *count* of the number of grid cells each point covers = 1), which makes the output a little harder to interpret. The rows from *min* to the right of the table all summarise the grid cell values for each point. However, since the summary is of a single pixel depicting a point, the *minimum* of all grid cells covered by each point, the *maximum*, and the *mean* are exactly the same – because there is only one grid cell per point and therefore there is only a single number to summarise. Each of these numbers contains the minimum sea depth in metres within 15km of each point, plucked out of our raster grid. Similarly, the *range* is zero because we are dealing with a single grid cell value, not many values. join using FID.

Now we need to link this information back to our map layer of sea bird census points, so we can compare fulmar abundance with this sea depth variable:

- right-click on **magseabirds** in the left-hand table of contents in ArcMap, then select *joins and relates*, then *join…*
- Choose **uniqueid** as the field that will be used to make the join (this contains numbers that match those in the sea depth file that we have just created)



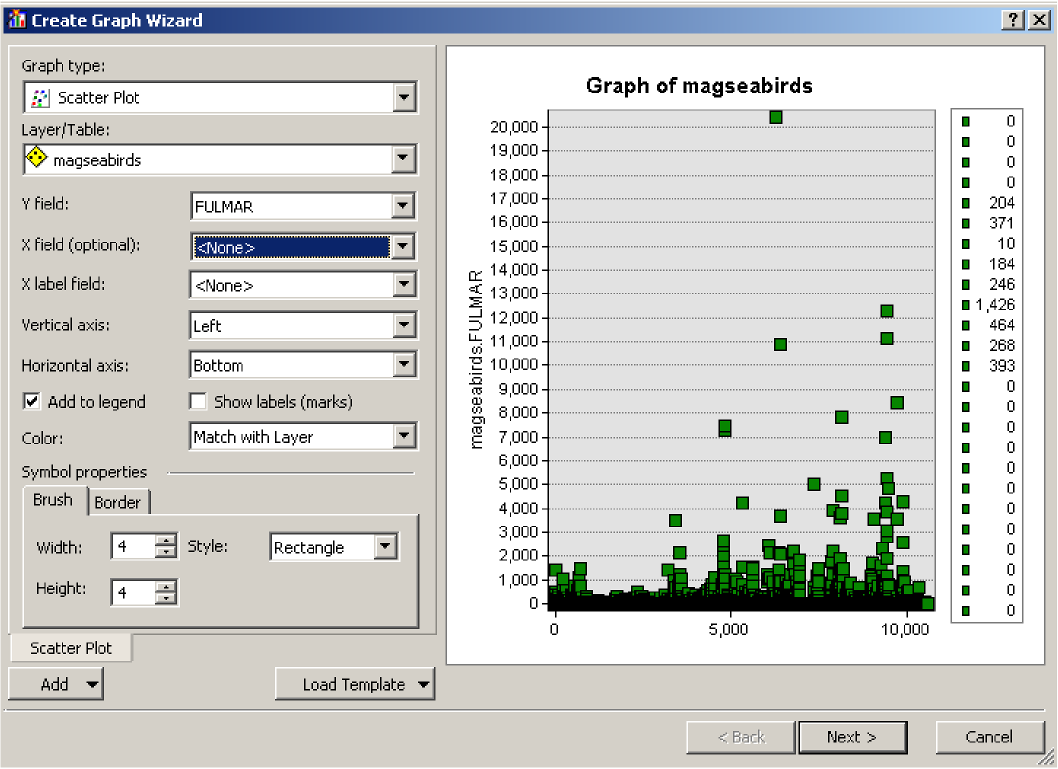
- For the table to join to this layer, select the data file that you have just created using *zonal statistics as table*
- Choose **oid** as the field to use in this table to make the join (**value** should also work, since it contains the same numbers)
- When you click OK, ArcView should join together the sea depth information with the sea bird census data, by matching the ID numbers in these two fields
- You may wish to make a permanent copy of the file with the sea depth information attached. To do this, right-click on **magseabirds**, then select *data / export data…* and enter in a name for the new shape file to be created, containing the additional sea depth data.

Produce a graph of fulmar abundance compared to sea depth

Now, we are in a position to generate a graph to see how fulmar abundance varies with sea depth.

- Go to the *view* menu, then select *graphs…* and then *create* (Note for ArcGIS version 9 users: this is on the *tools* menu under *graph* in earlier versions of the software).
- select as the *graph type* the option **scatter plot**
- choose the file that you just saved as the *layer/table*

- For the *Y field*, select **fulmar**
- For the X field, select any one of **mean, min** or **max** – as noted earlier, all of these should contain exactly the same sea depth information.
- Under *brush*, you may wish to make the *width* and *height* of each point on the graph a little smaller and perhaps vary the symbol used (there are many points on this graph and they tend to overplot one another).



- using the *add* button at the bottom left of the graph, you may wish to add in a trend line that shows the general direction of any relationship between sea depth and fulmar abundance

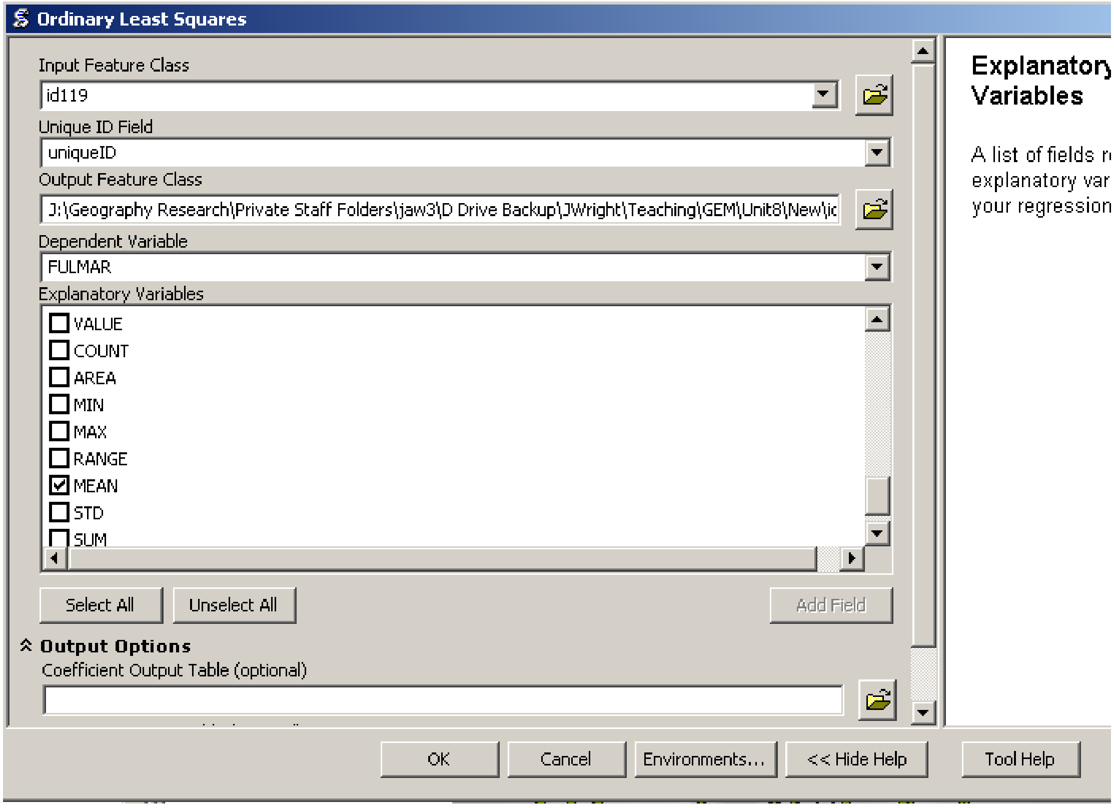
3. Based on your graph, do you think that there is a link between sea depth and fulmar counts? [turn to end of exercise for suggested answers]
4. What could you do to modify or improve on the analysis that we have carried out here? [One suggestion is at the end of this exercise. If you wish, you can also post any ideas you have to the course discussion board.]

For those with ArcGIS v9.3, v10 or later: carry out a statistical analysis of fulmar abundance versus sea depth

Those with a copy of ArcGIS v9.3 or v10 will also find an option to analyse the relationship between two or more vector map layers using the statistical technique of multiple linear regression (as well as a more advanced technique known as geographically weighted regression). In effect, this technique involves estimating a 'best fit' line that shows the relationship between two variables, rather as we did graphically in this exercise with fulmar abundance and sea depth. It is beyond the scope of this exercise to cover regression analysis in any detail. However, if you already have some familiarity with regression analysis, you may wish to read further.

Using this technique, we can find out which points are furthest from the best fit line by examining a map of residuals (in other words, we can see on a map how far away the sea bird count at each point is, in terms of its distance on the graph from the trend line we fitted earlier).

- In the ArcToolBox, select *spatial statistics / analyse patterns / linear regression*
- Choose your shape file with sea bird counts and sea depth joined to the data as the *input feature class*
- Choose a suitable name for the *output feature class*
- The *dependent variable* is the characteristic that we are trying to predict, which in this case is fulmar abundance – **fulmar**
- The *explanatory variables* are variables that we think might account for the distribution of fulmars. In our example, this is sea depth, which is stored in the **mean, min or max** fields – choose one of these fields.
- Those of you who have used regression analysis before may wish to select optional *output options* such as sea.
- When we press OK, ArcGIS generates a map, which shows the residuals from a simple linear regression of sea depth on fulmar abundance (the residuals represent the component of sea bird abundance that we have been unable to explain using sea depth).



In this particular example, we have not uncovered a relationship between sea depth and fulmar abundance, so the patterns in the residuals shown on this map will largely reflect the original map of fulmar distribution that we produced at the start of this exercise. However, in situations where a relationship has been found between an environmental characteristic and species numbers, this tool is useful for identifying those parts of a study area where a general relationship (identified through regression analysis) does not seem to hold.

Suggested answers to questions during exercise:

1. Fulmars are concentrated in northern parts of the British Isles, particularly on islands.
2. The etopo1 sea depth / elevation data are in geographic co-ordinates, referenced to the WGS 1984 datum. The sea bird census data are in British National Grid co-ordinates. ArcMap can cope up to a point with the different co-ordinate systems and reprojects the raster grid in British National Grid co-ordinates 'on the fly' (i.e. temporarily for display purposes). However, the warning message is really ArcMap asking for specific advice as to how to handle the difference in datums.
3. The linear trend line on the graph appears flat and parallel with the X-axis, which suggests that there is no evidence here for a link between sea depth and fulmar abundance. If there is a relationship between fulmar abundance and sea depth, it is not a simple, linear one (another way of thinking about this trend line is that it suggests on average, fulmar abundance does not increase as sea depth increases).
4. There are a great many options for further analysis! To take just one example, the Canadian analysis of fulmars and sea depth suggests that the influence of sea depth is only pronounced in more northern latitudes, where fulmars are more commonly found. We could restrict our analysis just to the northerly part of the British Isles by selecting just those sea bird census points to the north of our study area.