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).

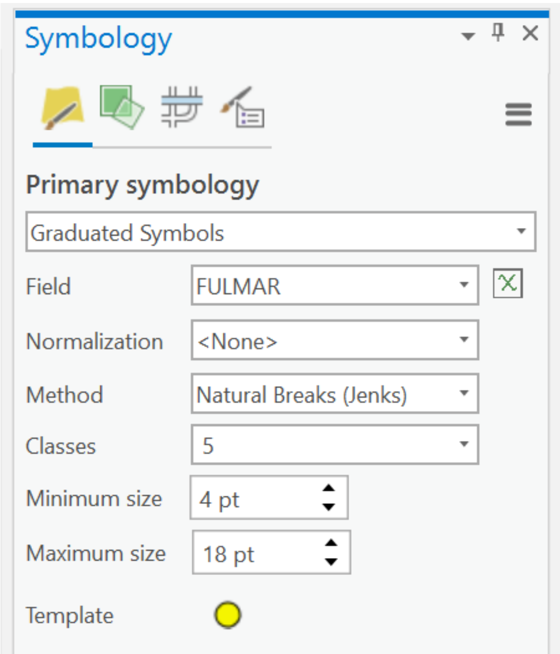
Instructions:

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

- Point your web browser to https://magic.defra.gov.uk/ to start downloading the seabird abundance data from the 2000 seabird census
- select 'our data sets' towards the bottom of the start-up screen
- Type in 'seabird' and then select dataset = 'seabird nesting counts (British Isles)' and select 'go'
- quickly read the meta-data about this data set, then accept the terms and conditions and download the data in shape file format

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 ArcGIS Pro (e.g. by dragging and dropping the layer from the catalog window).

Next, shade in the fulmar abundance data by right-clicking on your new **magseabirds** shape file and selecting *symbology*, then select as *primary symbology* **graduated symbols** and under *field*, select **fulmar.**

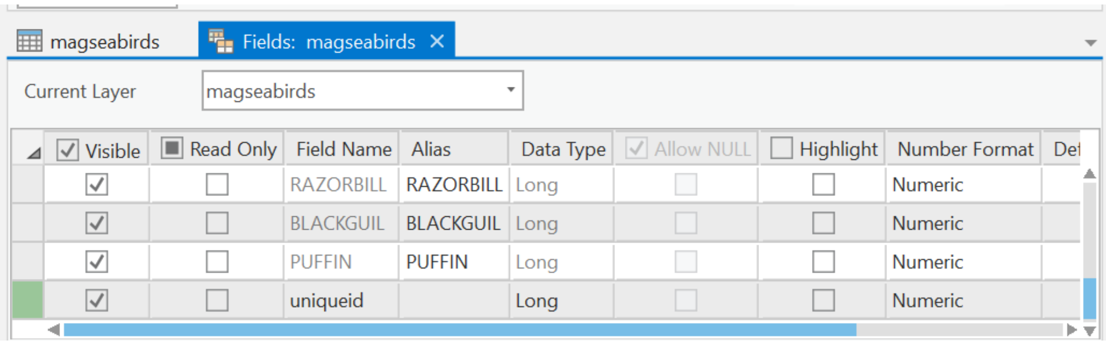


You should now see a map displaying fulmar counts around the British Isles – the larger the circle, the greater the number of fulmars observed at each location.

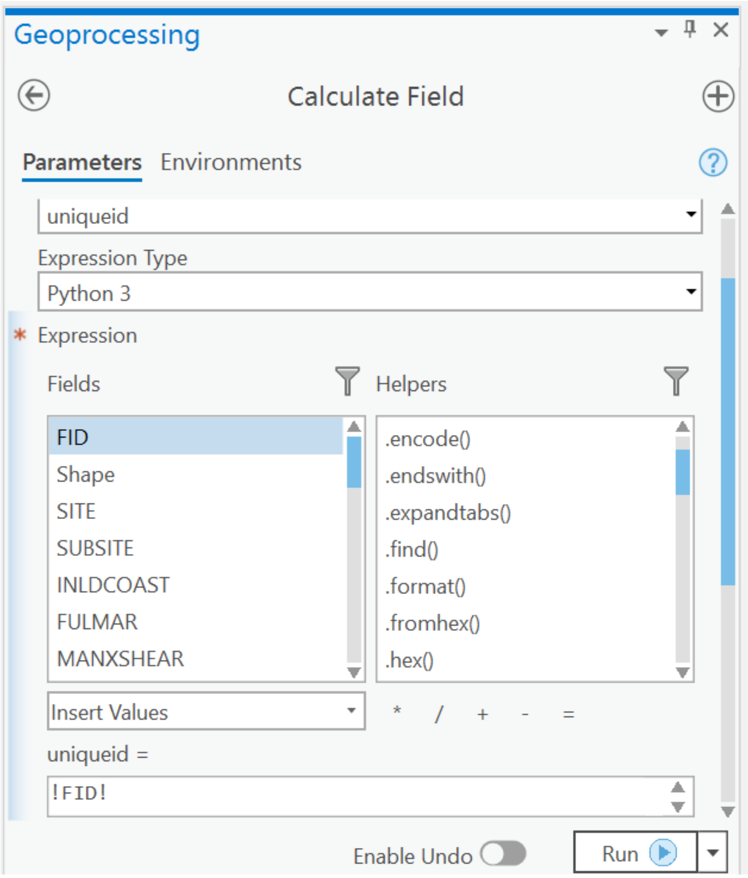
1. What do you notice about the spatial distribution of fulmars (turn to the end of the exercise for answer)

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 *attribute table*
- click on the *add* button at the toop of the screen …
- Create a new field of type **long** called **uniqueid**



- On the menu ribbon, press 'save' so that this field is added to your table.
- 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*
- In the right-hand panel, under *fields*, double-click on **fid** so that it appears in the box at the foot of this dialog box (where it says *[uniqueid] =*). Make sure you close down any open views of your table at the foot of your screen (if you do not do this, then you will receive an error message!), then click on Run.
- FID now 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:



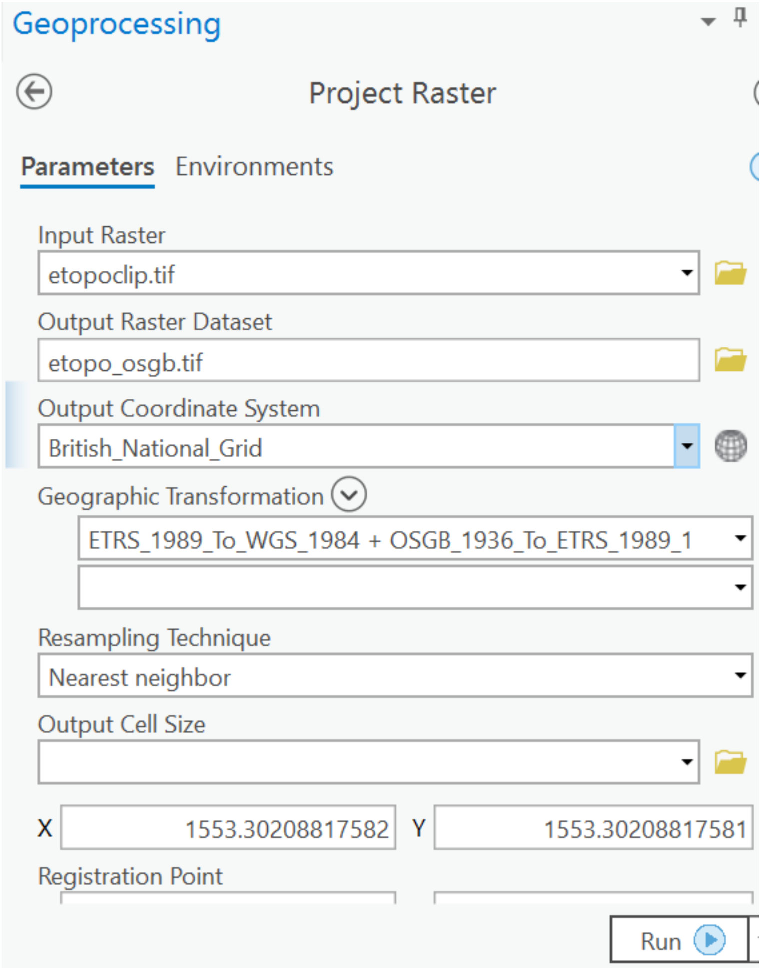
Prepare the sea depth data:

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

Since we will be working with raster data, head for the *project* menu, then *licencing* and then choose *Configure your licencing options.* Then make sure that the licence for *spatial analyst* is activated.

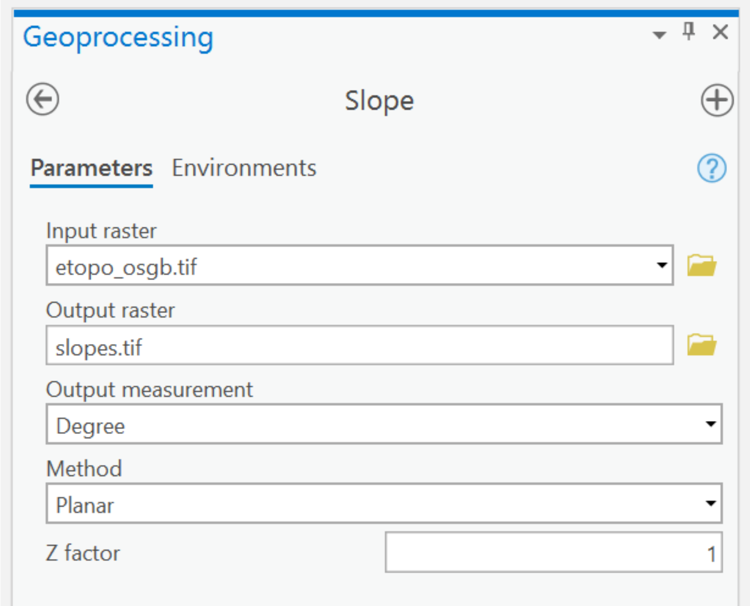
Next, head for the *Analysis* menu, then choose *tools* on the ribbon to bring up the geoprocessing panel on the right. Search for 'project' in this panel and then run the '*project raster'* tool.

- As the input raster, choose **etopoclip.tif.**
- Choose a suitable output raster file name, then set the *output coordinate system* to be the same as **magseabirds** (i.e. British National Grid):



The tool should output a version of the elevation raster, reprojected to British National Grid, so that both elevation and seabird census layers have the same coordinate reference system.

It might also be a good idea also to see if we can identify where there are cliffs suitable for nest sites, which we may be able to identify through slopes. So, head for the geoprocessing panel again, but this time, search for 'slope' and then run the *slope* tool, setting your reprojected elevation layer as the input:

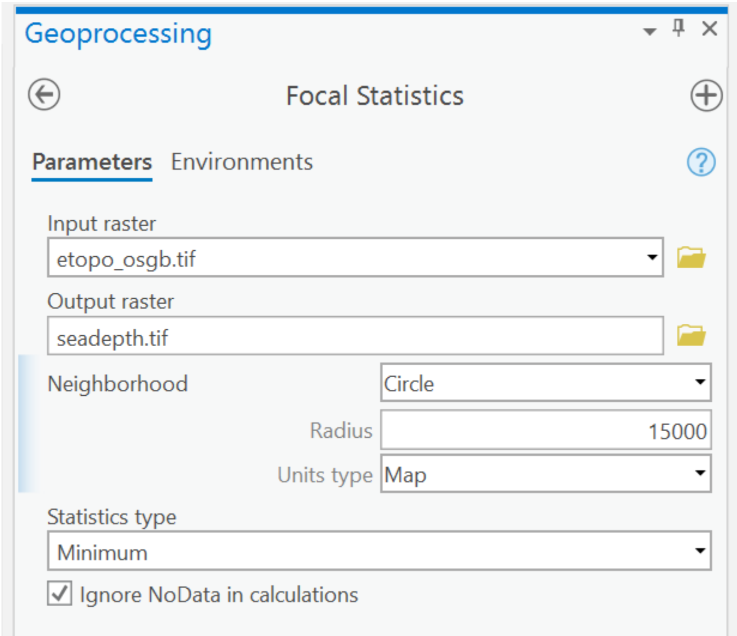


Generate a sea depth variable

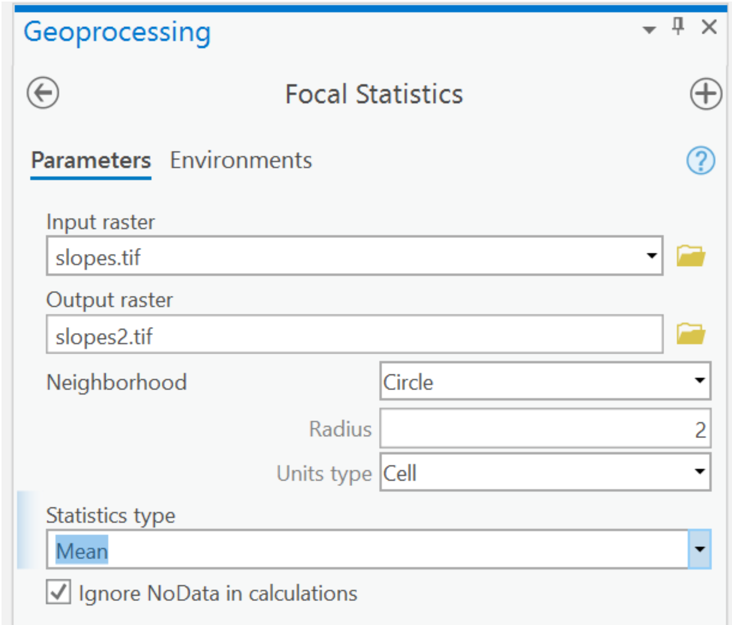
We now have our bathymetry / elevation data and sea bird data in the same coordinate system. However, we are really interested in capturing the characteristics of the sea area over which the fulmars are foraging, not the characteristic of the nest site itself. To find out about the broader environment 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 geoprocessing panel, search for 'focal' and then run *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.



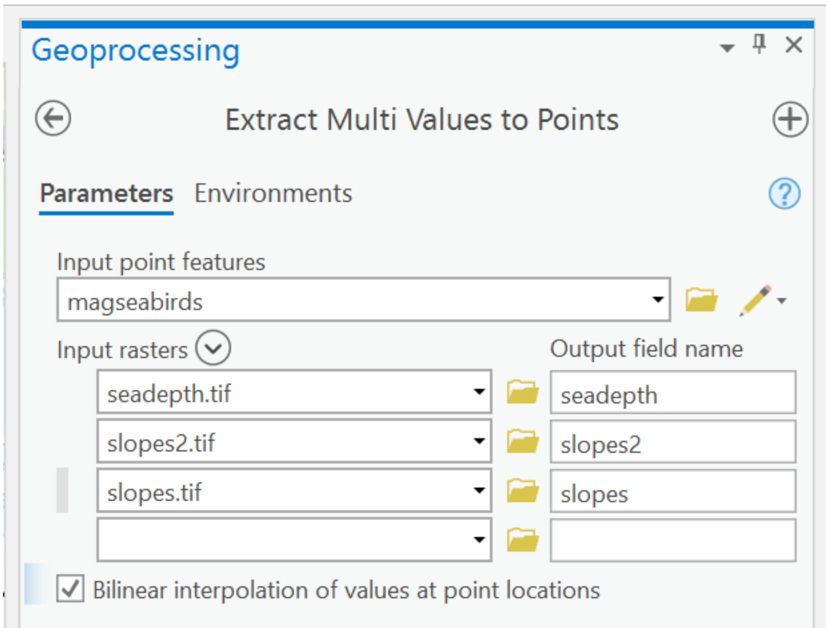
Slopes tell us about where seabirds are nesting, rather than where they are foraging. We therefore do not need to run 'focal statistics' for this layer. However, you may wish to run this 'focal statistics' tool again, in case there is any misregistration or positional error of the seabird census points relative to the slope layer that we created. If we run it again for slopes but with *units type* set to **cell** and a radius of 2, we should be able to work out the mean slope within 2 cells of each seabird census point:



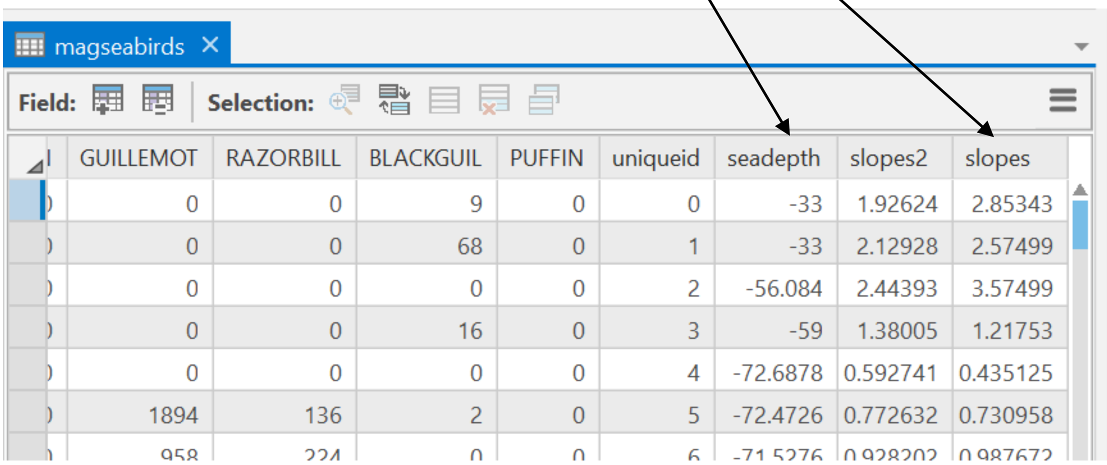
Calculate sea depth and slope for each bird census point

We now need to extract sea depth and slope information for each of the points in our data file automatically. We can do this using the *extract multivalues to points* tool:

- Again within the geoprocessing panel, search for 'extract multi' and then run '*extract multi values to points'* (note: extract values to points pulls out the value from the raster pixels that lie beneath each point in a vector file; extract multi values to points does the same operation, but can do this for multiple raster grids).
- As the *Input point features*, select your sea birds point layer
- For the *Input rasters,* select the raster grid generated by the focal statistics routine earlier, and also your slope layer(s).
- If you tick 'bilinear interpolation', where a point falls between raster grid pixels, then its value will be interpolated from the four surrounding pixel values.



When you click OK, the software will add new fields to your sea bird census map layer, with the underlying raster pixel values at each point for each input raster layer:



GUILLEMOT	RAZORBILL	BLACKGUIL	PUFFIN	uniqueid	seadepth	slopes2	slopes
0	0	9	0	0	-33	1.92624	2.85343
0	0	68	0	1	-33	2.12928	2.57499
0	0	0	0	2	-56.084	2.44393	3.57499
0	0	16	0	3	-59	1.38005	1.21753
0	0	0	0	4	-72.6878	0.592741	0.435125
1894	136	2	0	5	-72.4726	0.772632	0.730958
958	224	0	0	6	-71.5276	0.928202	0.987672

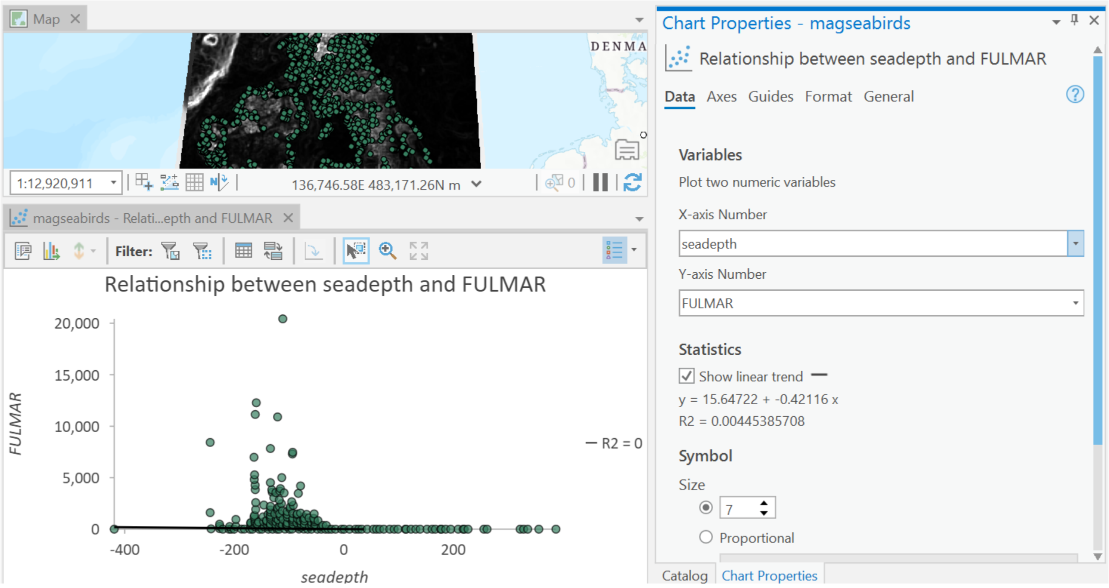
If you right-click on the sea bird layer and choose *attribute table*, you should be able to see this, as shown above.

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 and slope. ArcGIS Pro sometimes loads up a list of attribute fields when a map layer is first displayed. To refresh the list of attribute fields to include the ones we have just calculated, you may therefore first need to remove the sea bird census layer from the left-hand contents panel and map display, then add it back in again.

Having done so, right-click on the sea bird census then choose *create chart*, and then *scatter plot* . Via the chart properties dialog box, you should then be able to:

- Choose **seadepth** (or **slopes**) as the *x-axis number*
- Choose **fulmar** as the *y-axis number* (i.e. the number of birds)
- If you leave 'show linear trend' checked, the software will include a best fit line through the data too:



- Note that by choosing the *general* tab in this dialog box, you can also change the x and y axis titles to something more meaningful

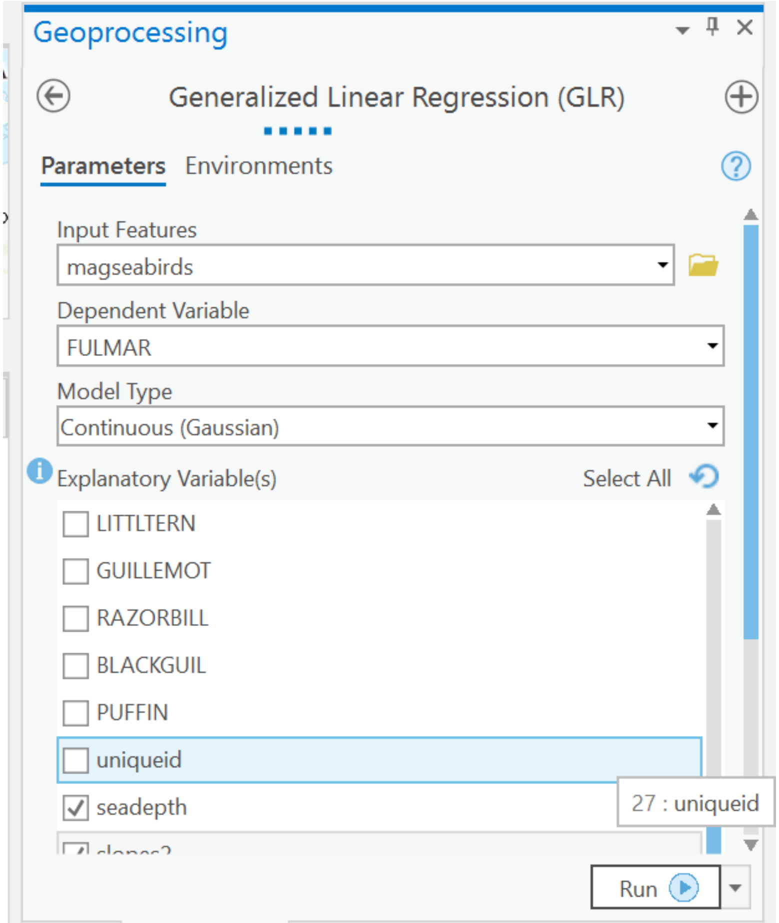
2. Based on your graph, do you think that there is a strong relationship between sea depth (or slopes) and fulmar counts? [turn to end of exercise for suggested answers]
3. What could you do to modify or improve on the analysis that we have carried out here? [One suggestion is at the end of this exercise.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

Statistical analysis of fulmar abundance versus sea depth

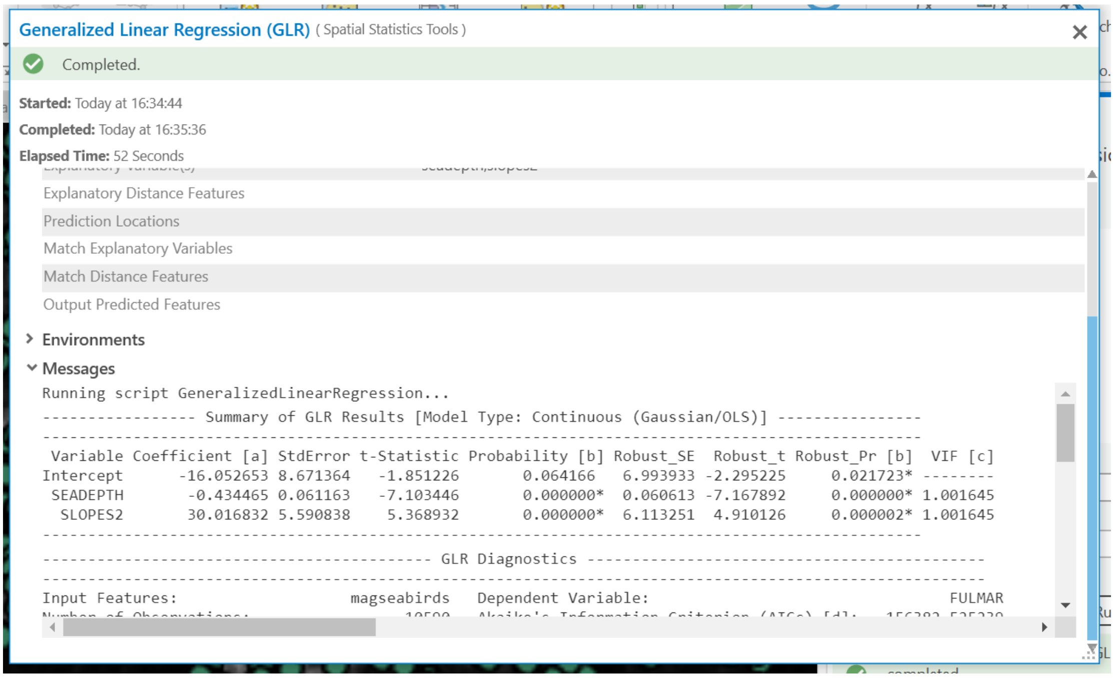
ArcGIS Pro also gives us the option to analyse the relationship between two or more attribute fields in a vector map layers using the statistical technique of multiple linear regression (as well as a more advanced technique known as geographically weighted regression). In effect, this technique involves 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 geoprocessing panel, search for "*regression"*
- Run '*generalised linear regression'*.
- Choose your shape file with sea bird counts and sea depth joined to the data as the *input features*
- 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 and slope, which is stored in the **seadepth** and **slope** fields – choose one or both of these fields (you may have called them something slightly different earlier).
- Note that you can also include other map layers as *Explanatory distance features* , though we will not use these here. These are map layers showing features whose proximity could affect the dependent variable. For example, if thought our seabirds were prone to disturbance, we could include footpaths, human settlements, or some other layer reflecting disturbance here.
- Those of you who have used regression analysis before may wish to select optional *output options* such as sea.
- When we press *Run*, ArcGIS Pro 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):



If you click on *view details* below the tool, you should be able to see under *Messages* some information about the regression model that was fitted to the data:



A detailed explanation of all the outputs is beyond the scope of this practical. However, as a brief summary:

- *Variable* tells us about each predictive variable we added to the model, as well as the intercept – the predicted value of seabird abundance when all other predictors are zero.
- The *coefficient* tells us about the impact of a one unit (of degrees or metres) change in the predictive variable on the number of fulmars. The positive coefficient for slopes suggests that as slopes increase, so does the fulmar abundance, whereas the negative coefficient for seadepth implies that as sea depth becomes shallower (increases), fulmar abundance decreases.
- The *probability* tells us how likely it is that the observed coefficient value could have occurred by chance alone. The closer to zero, the less likely it is that the coefficient could have been observed by chance, and if the probability is below 0.05, it would be seen as potentially statistically significant. In the output above, both sea depth and slopes appear to be statistically significant.

In addition to these statistics concerning each predictor added to our model, there are also some statistics that provide a summary of the model and its predictive capabilities overall. Again, a full description is well beyond the scope of this practical. However, two key figures here are:

- *No of observations:* We have 10590 input points. With so much data to work with, even very weak relationships may be significant.
- *Multiple R squared*: This is a measure of the amount of variation in seabird numbers explained by our two predictors. In my case, this value was 0.007, suggesting only 0.7% of the variation in seabird numbers was explained by the two predictors.

In this particular example, we have therefore uncovered only very weak relationships between sea depth, slope 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 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).
3. 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.