Measuring landscape patterns – understanding Macro Moth habitat

Scenario: understanding species habitats

GIS is commonly used to predict where a species will be found on the basis of environmental characteristics such as climate or vegetation type. Typically, the link is made through a Habitat Suitability Index. Habitat Suitability Indices (HSIs) predict the abundance or probability of finding a species from environmental characteristics. An HSI can either be created by statistically analysing the known range of a species, based on expert ecological knowledge of a species' habitat preferences, or some combination of these two approaches. HSIs can be used to predict how climate change or changes in land use policy (e.g. grants for afforestation or schemes to set aside land from agriculture) can affect wildlife. In creating an HSI, it can be important to consider not only individual elements within the landscape (such as the proportion of forest cover), but their overall pattern. This practical explores how landscape patterns can be measured within GIS.

In this scenario, you are working for the UK Office of the Deputy Prime Minister (ODPM) as a GIS analyst. The ODPM is planning to expand housing construction in many parts of the country and wishes to evaluate the ecological impacts of doing so. To better understand the relationship between urban land (and land cover more generally) and wildlife distributions, you have been provided with data on the distribution of several moth species for the UK. By understanding the relationship between current land cover – including urban land – and moth distributions, you should be able to predict how new housing will affect moth distributions in the future. First, however, you need to understand the relationship between the present moth distribution and current land cover…

The Data:

The following raster map layers are available:

- **peppered_moth**: the known range of the peppered moth in the UK, based on information from the Biological Records Centre in Cambridge, which manages all records of species locations in the UK. In ecology, a species range is the area(s) in which that species is known to occur. This raster grid identifies areas where the peppered moth is rare, common or very common. These areas have different numeric codes (stored in the **value** field) as follows:

```
code      0 : sea
code      1 : rare
code      2 : quite common
code      3 : very common
```

- **landcover**: a Landsat-derived map of land cover in Great Britain, taken from the Land Cover Map 2000. Each grid square contains the most common land cover type in that square. These areas have different numeric codes (stored in the **value** field) as follows:

```
code      0 : sea
code      1 : broadleaf
code      2 : urban
code      3 : coastal
code      4 : conifer
code      5 : improved_grassland
code      6 : open_water
code      7 : sea_unclassified
code      8 : semi_natural
code      9 : upland
code     10 : arable_hortic
```

- **urban_percent**: the percentage of urban land in each square
- **upland_percent:** the percentage of upland vegetation (moorland, etc.) in each grid square.
- **Brindled_moth:** the known range of the brindled beauty moth in the UK, based on information from the Biological Records Centre. The data are structured and coded as for the peppered moth.

GIS Practical:

Import and inspect your data

Unzip and then explore the imported files using ArcGIS Pro.

Look at the relationship between urban land, upland and peppered moths

Task 1:
Work out the average percentage of urban land and percentage of upland vegetation in the 3 zones where peppered moths are rare, common and very common (if you wish, add your answer to the table below).

	Rare	**Common**	**Very common**
% urban land			
% upland			

On the basis of this information, do you think that the peppered moth prefers urban land as a habitat, actively avoids it, or is indifferent to it? Does it have a preference for upland vegetation? Hint: If you are unsure about where to start on this task, full instructions are provided on the following page.

Hint: In the geoprocessing tools, you can use the 'zonal statistics as table' command to perform this analysis:

- You should specify the **peppered_moth** raster as the *input raster or feature zone data* with **value** (the numbers depicting the levels of moth abundance in the raster grid) as the *zone field*.
- The input value raster should be your **urban_perc** map of percentage land cover.
- The output table will hold the results. You will need to open this table up by first looking for it under *standalone tables* in the left-hand contents panel, then right-clicking on it and choosing *open*.

This tool will summarise the percentage urban land cover figures in each of the three classes of moth abundance. The numeric codes for each category of peppered moth abundance appear in the rows (i.e. 0=sea; 1=rare; 2=quite common; 3=very common). Summary statistics for the **urban_perc** map layer appear as different fields in your output table. For example, **sum** contains the total value of all the **urban_perc** pixels lying within each moth abundance category (see illustration below).

Attributes of ZonalSt_peppere1

OID	VALUE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD
0	0	4712	471200000000	-0.000008	80.7	80.7	0.036460	1.37669
1	1	1476	147600000000	-0.000008	86.2	86.2	2.69648	8.60896
2	2	811	81100000000	-0.000008	98.9	98.9	8.80826	17.7996
3	3	261	26100000000	-0.000008	100	100	17.1238	26.62

The most useful summary statistic for us here is stored in the **mean** field. This contains the average percentage of urban land in each moth abundance category.

Now trying running the same calculation using *zonal statistics as table* for the peppered moth distribution and upland vegetation.

Box 1 (note that you do not have to complete the tasks in this box in order to complete the exercise): A note about the raster analysis settings:

- If you right-click on the **peppered_moth** map layer in the left-hand panel and select *properties* and then the *source* tab, you should see a setting there called *raster information*. This indicates the cell size of each individual raster grid cell (pixel) in metres – which are 10,000 m by 10,000 m. Do the same for the **landcover** map layer and you should see that the *cell size* is 1,000 by 1,000 metres, so the land cover grid is much finer resolution.
- When you run a spatial analyst tool such as *zonal statistics as table*, you can decide which grid cell resolution will be used in calculations. You can do this by clicking on the *environments* tab and choosing *raster analysis*. The default value here (*maximum of inputs*) means that the coarsest resolution of 10,000 by 10,000 metres will be used.

- You can override this and set this to be 1,000 by 1,000 metres (e.g. by choosing *minimum of inputs*). This can sometimes make a difference to the results of such calculations.

Measuring Landscape Composition

So far, we have looked at the distribution of the peppered moth in relation to two habitat characteristics – urban land cover and upland vegetation. However, many animals do not solely require a single type of habitat. Some species rely on a mixture of habitat – many birds, for example, will nest in woodland but feed in grassland. For these species, what is important is not the presence or absence of any one land cover class, but a mosaic of different habitats in the same neighbourhood. We therefore need a measure of landscape composition or pattern.

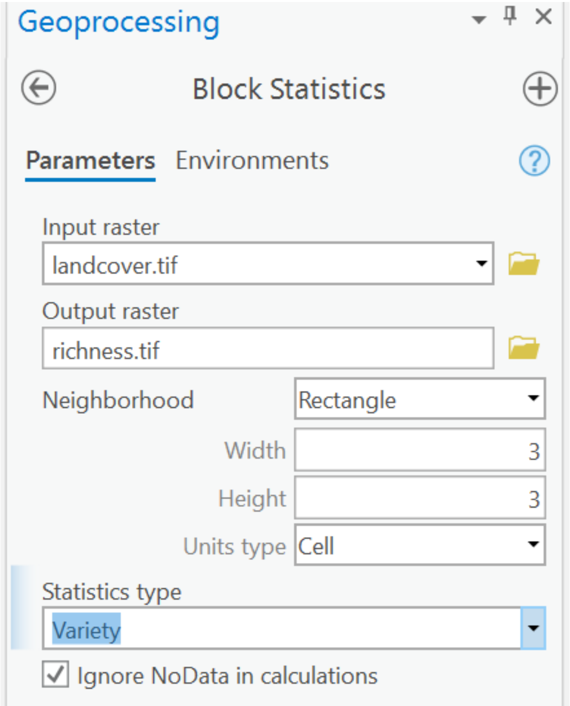
One measure of landscape pattern is called relative richness. Relative richness measures the percentage or proportion of all the possible land cover classes available that appear in a given sub-region of a model. When expressed as a percentage, relative richness of 100% indicates all classes are present in a sub-region, whilst relative richness of 0% indicates that only one land cover class is present in a sub-region. Typically, the sub-region is a 'box' containing 9 pixels that can be moved across the study area.

Look at the map layer called **landcover**. Make a note of the total number of different land cover classes (i.e. urban, upland, semi-natural, etc.) that you can see on this image:

Number of different classes: _________________

We can calculate relative richness from this landcover map as follows:

- In the geoprocessing panel, go to *spatial analyst tools*, and then choose *neighbourhood.* Select *block statistics.*
- Choose **landcover** as your *input raster* and enter an appropriate name for your output raster, such as **richness**.
- Leave the neighbourhood set to *rectangle* and to 3 by 3 cells (the **landcover** map has cells that are 1km by 1km, so this means that we will calculate relative richness for areas that are 3 by 3km).
- Under *statistics type*, select *variety*. This will calculate the number of unique values stored in each group of 3 by 3 pixels across the raster grid. In effect, since each value represents a different land cover type, this is calculating the number of different land cover types in a moving 'window' that is 3 by 3km.



You should now see a measure of landscape richness – low numbers indicate areas that are completely agricultural, completely urban, etc. High numbers indicate a 'mosaic' of different types of land cover.

Our output raster gives us the total number of land cover classes in each 3 by 3km 'window'. However, relative richness is normally expressed as a percentage or proportion of the total number of land cover classes in an image. To express relative richness as a proportion, we need to do the following:

- We need to divide our raster grid by the total number of land cover classes in the whole image.
- Go to the geoprocessing panel once again, search for 'divide', then select *divide.* Choose **richness** as the *input raster or constant value 1* and for the *input raster or constant value 2*, enter the number of land cover classes that you wrote down on the previous page (this will divide each cell in the **richness** raster by this single number). You also need to specify a name for your *output raster*, such as **richnessb**.

Landscape relative richness and the peppered moth

We now have 3 measures of landscape relative richness at different scales, but is there any evidence that the peppered moth responds to landscape richness?

Task 2: Using the same methodology as you used for the upland and urban land cover map layers, use ArcGIS Pro to assess whether or not the peppered moth distribution appears to vary in line with relative richness.

Summary and Further Questions:

As an example of the many different types of measures available here, we have calculated just one measure (relative richness) in ArcGIS Pro, which happens to be fairly easy to calculate. In a 'real world' application of landscape ecology techniques, it should be borne in mind that the choice of measure used would normally be based on the ecology of the species being investigated. This is important in two respects:

- We could have looked at landscape relative richness at many different scales. Here, we measured relative richness for rectangular areas of 3 by 3km. However, if expert ecological opinion from the field suggested the landscape scale as experienced by the peppered moth was different to this, we could have looked at relative richness at broader scales (e.g. 5 by 5km or 10 by 10km) or – with other data – finer scales.
- Different species respond to different aspects of a landscape's composition. There are many different measures used in landscape ecology and relative richness is just one of them. To take just one other example, there are also fragmentation indices, which describe how far a land cover class is broken up into small patches within the landscape. Again, based on expert opinion from the field about a particular species, it may be appropriate to look at other landscape ecology measures and not just relative richness.

Further questions (optional):

- If you were to look at relative richness over broader scales (e.g. 5 by 5km or 10 by 10km), how might you do this?
- We have looked here at the peppered moth. You may wish to try out the same analysis on the brindled moth data set, which is also provided with this exercise.

Optional extension activity – patch landscape metrics:

The richness measure we have calculated tells us about the local composition of land cover classes in the environment. We can also generate metrics about patches – individual land cover polygons of broadly homogenous habitat. Compactness is an example of a patch characteristics that can affect ecological processes. For example, at the margins of a patch of suitable habitat, a species may be more susceptible to predation.

One way of measuring the shape of land cover patches is to use compactness ratio, the ratio of a patch's area to the area of a circle with the same perimeter. This can be calculated as:

Compactness ratio = $4\Pi a/p^2$

[Where a = patch area and p = patch perimeter; Π is 3.142]

ArcGIS Pro has a tool called *Zonal Geometry*, which can calculate the area and perimeter of contiguous groups of pixels sharing the same integer (whole number) values within a raster map layer. It also has a *raster calculator* tool, which we could have used instead of the *divide* tool earlier. Can you find a way of using these tools with the **landcover** layer to calculate the compactness ratio of different land cover patches?

References:

The distributions of the peppered moth and brindled moth are derived from the MapMate Digital Atlas of scarcer Macro Moth species, copyright Biological Records Centre. See www.mapmate.co.uk/downloads.html

The land cover data are derived from the public domain Countryside Information System software and related data and are themselves from the Centre for Ecology and Hydrology Land Cover Map of Great Britain 2000. (see: http://science.ceh.ac.uk/data/lcm/LCM2000.shtm)