An assessment of relative landscape isolation for badgers (*Meles meles*) within Wales

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Executive Summary

- The aim of this project was to develop a model for Wales indicating the relative isolation of the landscape in terms of badger migration.

- A least-cost modelling approach was used within a geographic information system. We used data on suitability of the landscape for badger setts in combination with expert opinion on the value of landscape features as barriers to badger movement, to produce estimates of relative isolation for Wales.

- Fourteen different scenarios were developed in which model input parameters were varied to reflect the range of expert opinion values for the barrier features.

- In all scenarios, the relative isolation varied across Wales, which would indicate that some parts of Wales are likely to be relatively more or less isolated than others.

- There was general consistency in the model outputs between the scenarios, with the relatively most isolated areas remaining so under each scenario.

- It is important to highlight that because the modelling exercise was carried out based on expert opinion and not empirical data on rates of badger movement, it is not possible to apply absolute values of permeability or isolation to the Welsh landscape. Hence the maps indicate how isolated one given area is likely to be relative to another.

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Introduction

In certain contexts, wildlife management strategies may be most effective if applied in areas where the target population is relatively isolated, and where the opportunities for population migration are limited. In the context of the management of badgers (*Meles meles*) to control bovine tuberculosis (bTB) in cattle, any future management strategy could potentially benefit from knowledge of relative isolation of areas for badgers across Wales.

The aim of this project was to develop a model surface for Wales indicating the relative isolation of the landscape to badger migration, based on the combination of landscape features present, and their ability to slow badger migration. This will facilitate the identification of areas in Wales that are relatively isolated or otherwise for badgers.

Very little data is available on badger movements at a large scale, and particularly on how different features in the landscape act to inhibit or promote badger movement. In the absence of quantitative information, a modelling exercise can be carried out using parameter estimates based on expert opinion. Hence, the modelling approach must be selected based on its ability to use qualitative expert opinion, and to incorporate and express the uncertainty associated with that opinion.

Therefore, the objective of this work was to produce two maps. The first would show the relative isolation of the landscape to badgers, which would allow the identification of those areas of Wales that are potentially more isolated than others. The second would establish the uncertainty associated with the estimates of relative isolation.

Methods

Least-cost modelling

Measurement of landscape connectivity was carried out using ‘least-cost modelling’ within a geographic information system (GIS) (Adriaensen *et al.* 2003). This method is based upon generating a friction surface, which is a raster GIS map in which each cell has a value that describes the permeability of that part of the landscape to the species of interest. This friction surface can be used to derive, for a given starting point, the degree of connectivity to all other parts of the landscape by calculating paths of maximum efficiency that balance distance and friction. A path of maximum efficiency is called a least-cost pathway (LCP), and has a cost-distance value that is a combination of the distance travelled and the cost of the friction associated with the landscape traversed (Fig.1a).

Least-cost modelling can be limited by specifying a maximum cost-distance value, which can be considered analogous to the maximum dispersal capability of the target species. By identifying all parts of the landscape that could be reached by a LCP with a cost-distance at or below the maximum cost-distance, a catchment area can be generated, defined as a cost-catchment (Fig.1b). In this current context, parts of the landscape with smaller cost-catchment areas will be considered to be relatively more isolated in terms of the badger population.

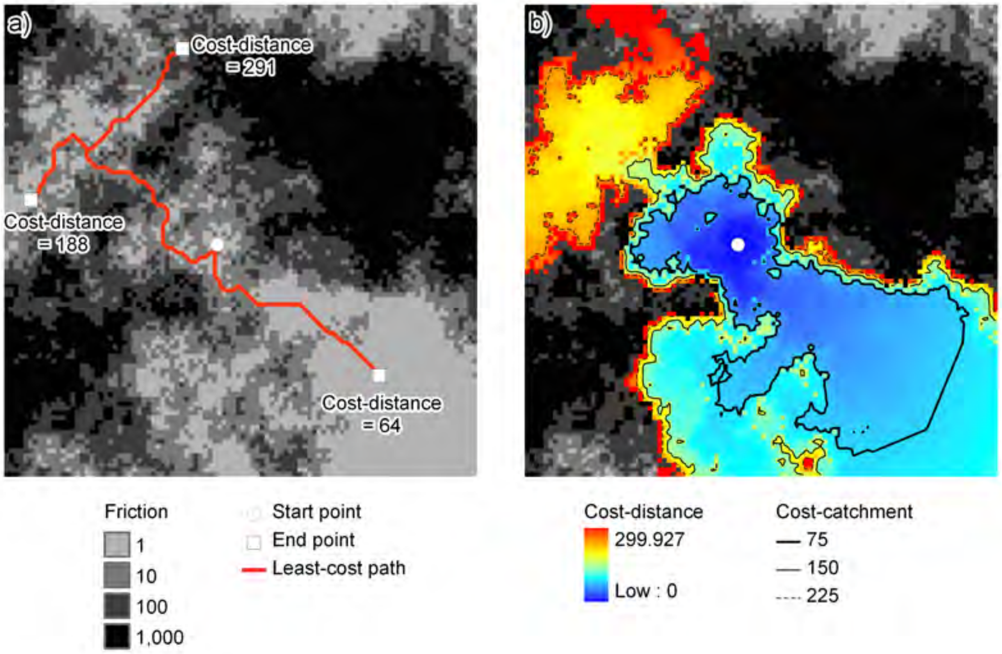

Figure 1. An example of the least-cost modelling process. In a) a friction surface is defined to identify those parts of the landscape that are more and less permeable. From a specified starting point a least-cost pathway (LCP) is determined to each end point. The LCP is the path of maximum efficiency accounting for distance and friction, and has an associated cost-distance value. In b) from the same starting point LCPs have been calculated for the whole landscape, but with a maximum cost-distance value of 300. The cost-catchment contours are based on different cost-distances, and illustrate how the size of a cost-catchment will alter depending on the maximum cost-distance value chosen.

The key element of this approach is the creation of the friction surface. This process begins with the creation of a base layer in which the friction value is 1. This means that in the absence of any additional barriers to movement, the cost-distance is equivalent to actual distance i.e. cost-distance = friction × distance, where friction = 1.

Further layers can then be added with pre-determined friction values in order to represent specific landscape features deemed to present a barrier to animal movement. It is important to recognise that each of the barriers identified will be expected to have differing degrees of impact on permeability. Therefore, each barrier layer is given a weighting to reflect its perceived relative importance to permeability. Hence, a barrier layer given a weighting of 4 will be twice as impermeable as a barrier given a weighting of 2. In the absence of empirical data on the permeability of landscape features, qualitative estimates of the relative importance of different features can be made, and cost-catchments calculated accordingly.

Application to badgers in Wales

The cell resolution used in least-cost modelling can be critical. If the cells are too large, then important detail within the landscape can be lost. However the desire for a small cell resolution has to be balanced against logistical issues of computation time, which increases as cell size decreases.

The key to this decision is ensuring that the cell resolution is fine enough to detect the patterns or features of interest, which in this case are the relatively more isolated parts of Wales for badgers. Given the size of Wales, and the fact that badgers will move distances of multiple kilometres (Neal and Cheeseman 1996, Pope *et al.* 2007), a cell resolution of $1km^2$ should be capable of discriminating areas of greater badger isolation, while retaining feasible computation times.

We were interested in barriers that may limit badger dispersal though a combination of physical limitations on movement, a psychological aversion to movement, and increased mortality during movement. There is a conspicuous lack of information available on what may or may not form a barrier to badger movement. Therefore, expert opinion was used to guide the modelling process. Nine experts were polled individually, each identifying features that were considered as having the potential to act as barriers to badger movement. Each feature was given a weighting to reflect its perceived relative importance as a barrier to movement, with an associated range where the maximum and minimum reflected the uncertainty of that feature's value as a barrier. The expert opinion was then combined to produce a mean weighting and range for each barrier feature.

The landscape features identified as being a barrier to badger movement were motorways and trunk A-roads (Fig.2a), large and medium rivers (Fig.2b), and poor badger habitat (Fig.2c). The data sources for, and pre-processing of the barrier layers, are detailed in Appendix One. Fourteen different combinations of landscape feature weightings were then selected as model inputs, chosen to reflect the range of uncertainty in the weightings provided by the expert opinion (Table 1). The coast and large bodies of open water were considered to be completely impermeable to badgers.

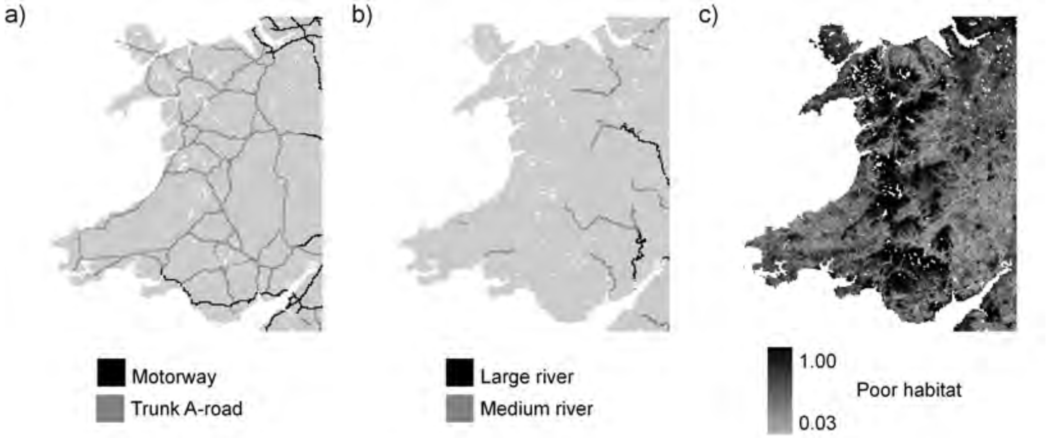

Figure 2. The distribution of landscape barriers to badger movement in Wales.

Maximum cost-distance values were also required in order to create cost-catchments. Given there is clear evidence that badgers are capable of moving several kilometres in the absence of large landscape barriers (Neal and Cheeseman 1996, Pope *et al.* 2007), and that our cost-distances are equivalent to actual distances in the absence of barriers, we used two maximum cost-distances of 5000m and 10000m. By using both values within the 14 scenarios, we would also be able to assess the impact of uncertainty in this value.

Table 1. Combinations of weightings for landscape features and values for maximum cost-distance used for model inputs in each scenario.

Scenario	Motorway	Trunk A-road	Large River	Medium River	Poor Habitat	Maximum Cost-distance
1	5	2	9	7	1	10000
2	5	2	9	7	1	5000
3	5	2	9	7	2	10000
4	5	2	9	7	2	5000
5	3	1.5	8.5	6	1	10000
6	3	1.5	8.5	6	1	5000
7	3	1.5	8.5	6	2	10000
8	3	1.5	8.5	6	2	5000
9	7	2.5	9.5	8	1	10000
10	7	2.5	9.5	8	1	5000
11	7	2.5	9.5	8	2	10000
12	7	2.5	9.5	8	2	5000
13	3	1.5	8.5	6	1	10000
14	7	2.5	9.5	8	2	5000

These model inputs in Table 1 were used to calculate a cost-catchment value for each 1km^2 cell in Wales under each of the fourteen scenarios. Hence the relative isolation of the landscape for badgers was modelled under a range of scenarios chosen to reflect the uncertainty in the value of the different barriers. From this it was possible to identify areas that consistently emerged as relatively more or less isolated. To enable comparison of the maps indicating relative isolation under the different scenarios, all cost-catchment scenarios were normalised. This involved dividing the cost-catchment values for each map by the maximum cost-catchment value for that map. This allowed all cost-catchment maps to be compared on a common scale ranging from 0, indicating the smallest cost-catchments and hence the relatively most isolated parts of the landscape, to 1, indicating the largest cost-catchments and hence the relatively least isolated parts of the landscape. We calculated the mean and standard deviation (SD) of these normalised isolation maps to look at the level of variation and hence confidence associated with the relative isolation across the scenarios.

Results

In all scenarios, the relative isolation varied considerable across Wales, which would indicate that some parts of Wales could be relatively more or less isolated than others (Fig.3 to Fig.6). There was also variation in the location of areas of relative isolation between scenarios, indicating that changes in the model input values (Table 1) had an affect on the estimates of permeability and hence relative isolation.

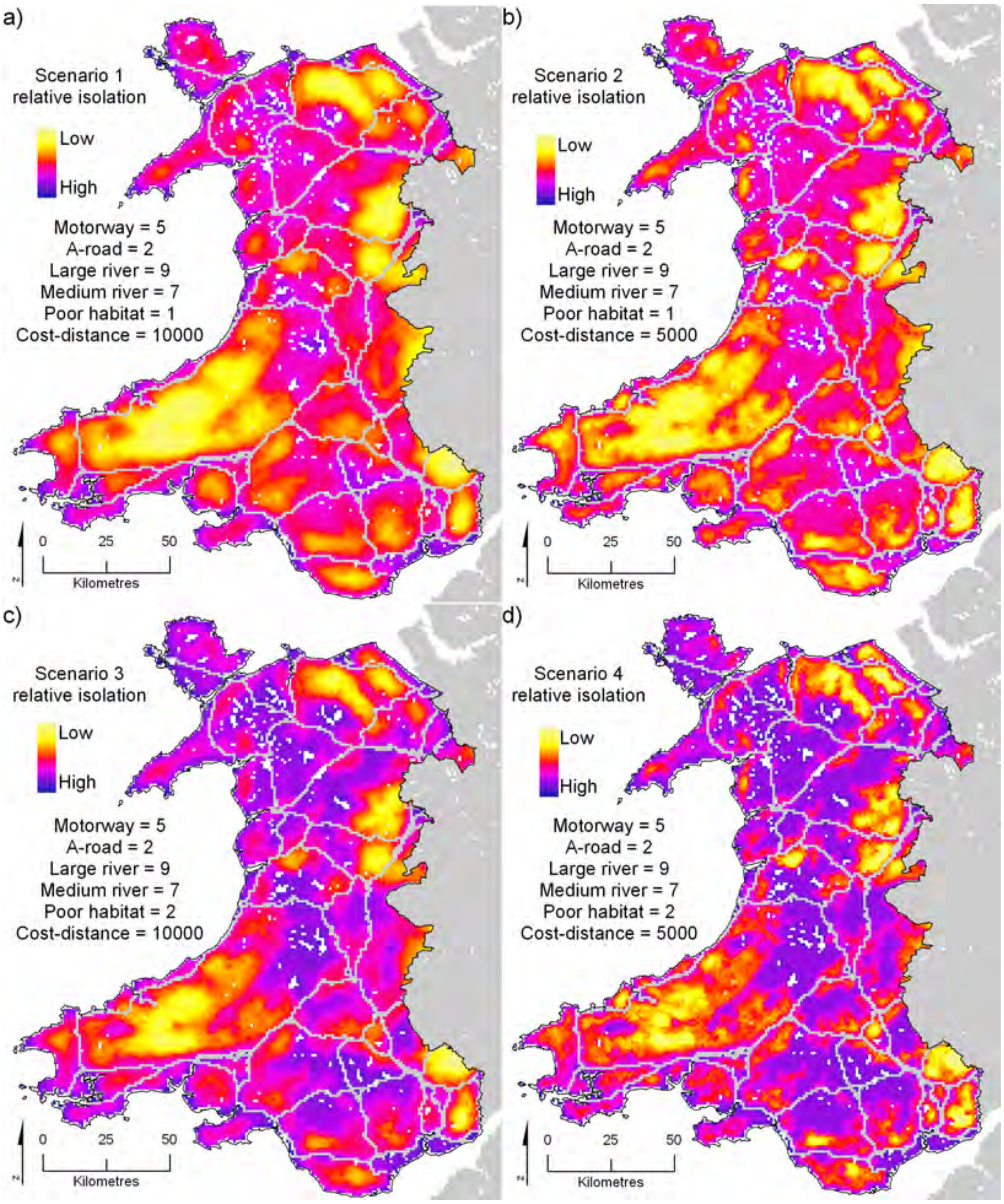

Figure 3. Relative isolation maps for scenarios 1 to 4. The weightings for each landscape feature are given, with higher values indicating relatively more effective barriers to badger movement, along with the maximum cost-distance value used to calculate the cost-catchment.

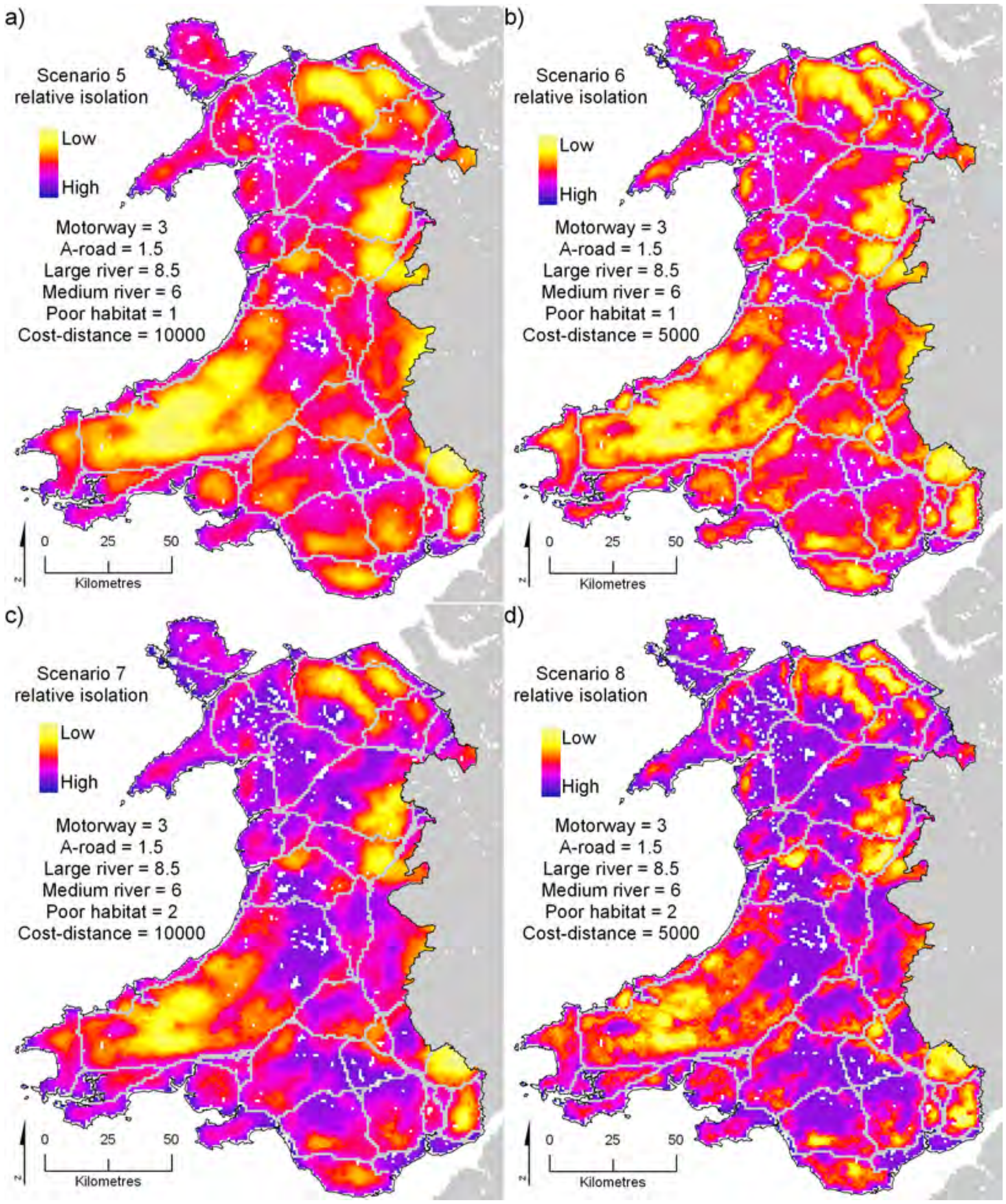

Figure 4. Relative isolation maps for scenarios 5 to 8. The weightings for each landscape feature are given, with higher values indicating relatively more effective barriers to badger movement, along with the maximum cost-distance value used to calculate the cost-catchment.

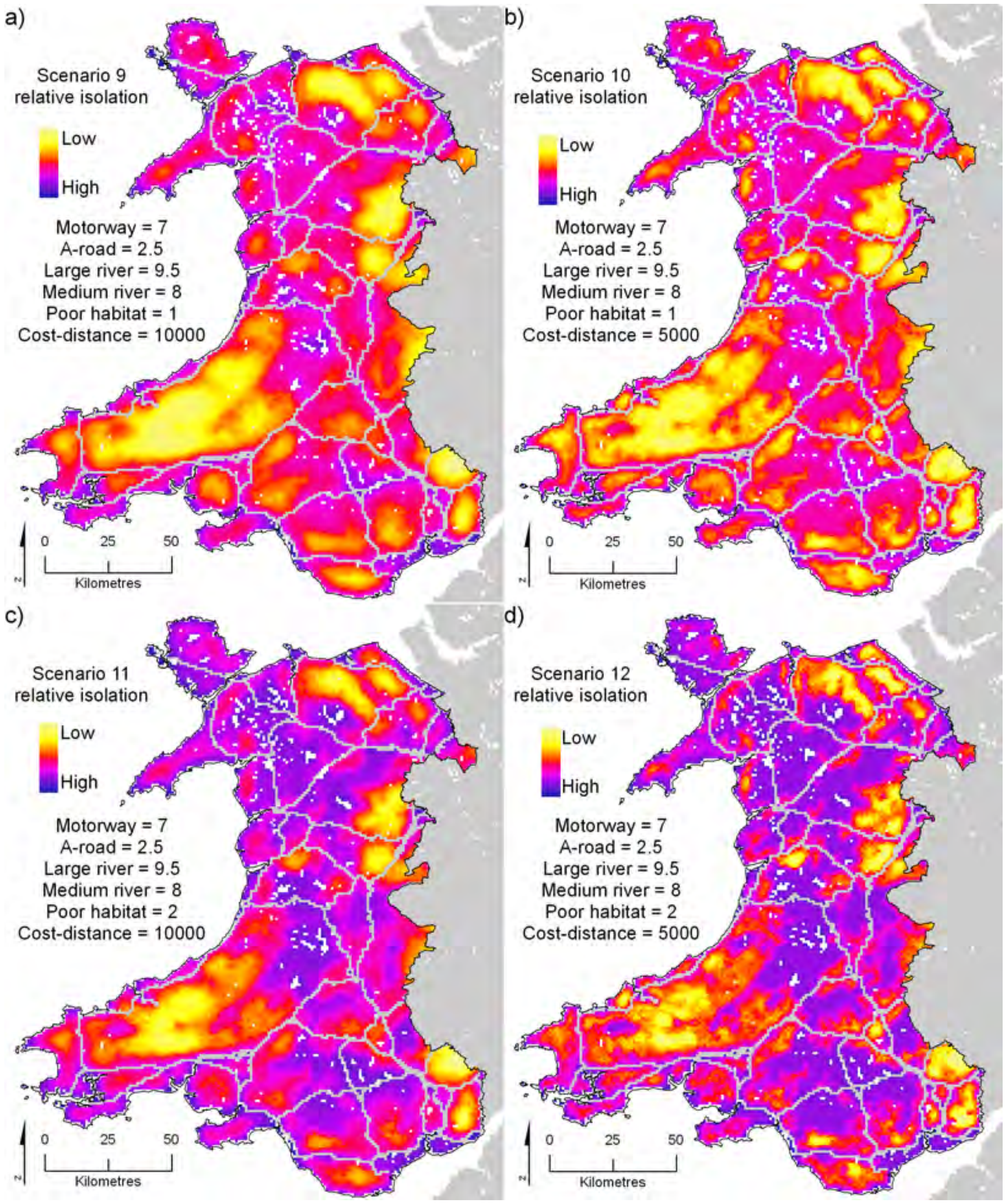

Figure 5. Relative isolation maps for scenarios 9 to 12. The weightings for each landscape feature are given, with higher values indicating relatively more effective barriers to badger movement, along with the maximum cost-distance value used to calculate the cost-catchment.

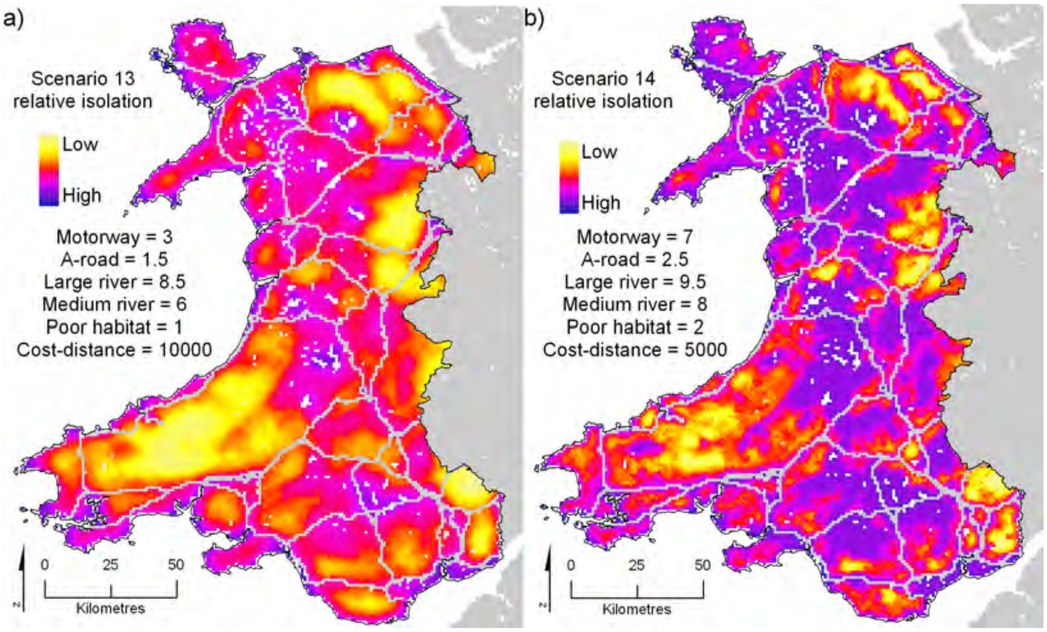

Figure 6. Relative isolation maps for scenarios 13 and 14. The weightings for each landscape feature are given, with higher values indicating relatively more effective barriers to badger movement, along with the maximum cost-distance value used to calculate the cost-catchment.

However there was also general consistency between the scenarios, with the relatively most isolated areas consistently occurring in the same geographical areas under each scenario. This consistency in relative isolation is illustrated in Fig.7b, where the SD values are quite low indicating that most areas remain relatively more or less isolated regardless of the scenario used. Even for those parts of Wales whose relative isolation varies the most depending on the model input scenario used, the maximum SD was only 0.179 on a scale of 0 to 1.

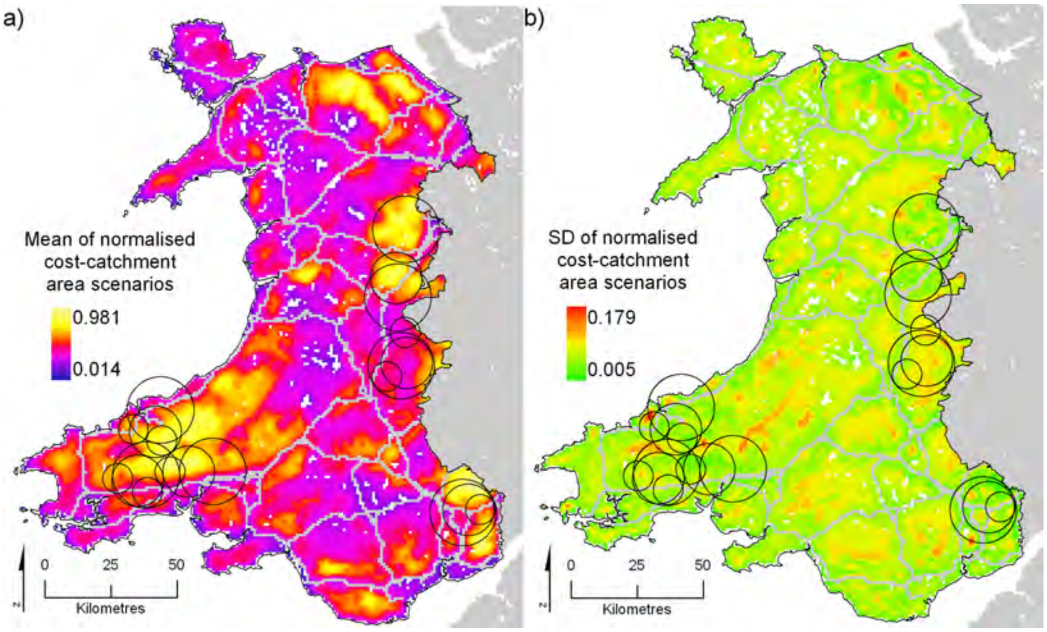

Figure 7. Maps showing a) the mean value of the normalised relative isolation maps for all 14 scenarios, and b) the associated standard deviation (SD). Also plotted are the candidate Intensive Action Pilot Area (IAPA) areas identified by the (VLA 2008). Darker green colours on the map showing SD indicate that the estimated relative isolation of that particular area is unlikely to change under different model input scenarios. Red colours indicate the opposite, i.e. that changes in the model input scenarios may result in greater variation in the estimated isolation values for that area.

Discussion

In the absence of empirical data on the rates of badger movement across different landscape features, this study has used expert opinion data on relative permeability to generate maps of the likely relative isolation of areas of the Welsh landscape to badger movement. From these maps it is possible to identify areas that are likely to be more isolated in badger population terms i.e. areas that are bounded by land that either holds only a small badger population, is less permeable to badger migration, or is a combination of both. Because the modelling exercise was carried out in part based on expert opinion and not field data, it is not possible to apply absolute values of permeability or isolation to the Welsh landscape. Hence the maps allow the comparison of the degree of relative isolation between areas. Changing the model inputs to reflect the range of weightings given to each barrier feature by the experts shifted the cost-catchment for each cell and varied the isolation of each cell, but the general patterns remained unchanged.

References

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<u>Appendix One – GI Data Sources</u>

Badger Habitat

Habitat data was based on a model of estimated suitability of the landscape for badger main setts (Etherington *et al.* in press). The resolution of this model was 100m, so it was generalised to a resolution of 1km taking the mean value for the new, larger cell. Any 1km cells containing a null cell from the original 100m-resolution map was also classified as null. Although this reduced detail around coastal areas in particular, this was carried out to ensure that features such as estuaries did not become permeable after generalisation.

The premise for using this data was that poor badger habitats, containing fewer main setts, were less permeable. Therefore in creating the habitat friction surface the values of main sett density were inverted before being rescaled to between 0 and 1.

Roads

Road data was taken from the Ordnance Survey (OS) Meridian 2 dataset. Two categories were used, trunk A-roads and motorways. These vector datasets were rasterised with a 1km resolution, with any cell with a polyline equal to 1.

Rivers

River data was taken from the European Commission Joint Research Centre Catchment Characterisation and Modelling (CCM) river and catchment database, version 2.1 (Vogt *et al.* 2007).

Permeability of a river for badgers was considered in relation to river width. Two size categories were identified, medium rivers having a width >=20m and large rivers a width >=40m. However, given that width was not a variable included with CCM, we developed a simple linear regression between cumulative length of a point along a river given by the CCM dataset, and the width of the river at that point as measured from aerial photography. This regression (Fig.6) was then applied to all river data within the CCM dataset, in order to identify those rivers of relevant width. Both river categories were rasterised at a 1km resolution, with cells valued at 1 where a river was present within the cell.

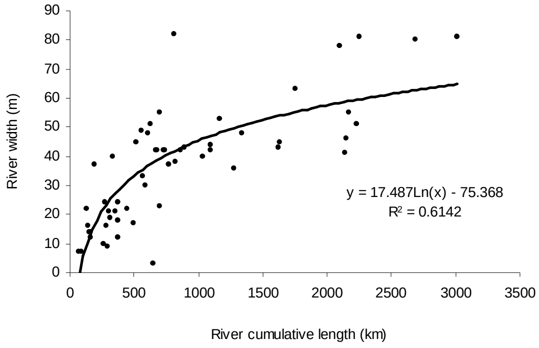

Figure 8. Regression of cumulative river length against river width.