Policy Brief – August 2008

IS THERE A CASE FOR MODIFYING FEATURES OF THE LANDSCAPE TO HELP SPECIES MOVE IN RESPONSE TO CLIMATE CHANGE?

(SUMMARY OF DEFRA CONTRACT CR0389)

Background

The UK Biodiversity Partnership has recently produced revised priorities for biodiversity conservation in the UK.[1] The central focus will be on protecting the best sites for wildlife and targeting action on priority species and habitats including helping biodiversity respond to climate change. It is likely that considerable numbers of species, including UK Biodiversity Action Plan priority species, may need to alter their range and distributions in response to projected changes in their "climate space" [2] – the geographical area within which the climate will be suitable for population survival.

Habitat fragmentation is thought to be a major factor constraining the ability of species to track geographical changes in their climate space. [3, 4] Habitat loss and degradation, the increase in isolation between habitat patches and the intensification of land use in the intervening landscape matrix threaten the ability of species to disperse and colonise new areas. [5, 6]

What is connectivity?

The development of ecological networks has been proposed as a mechanism for improving connectivity and facilitating species dispersal as an adaptation to climate change. [7] Connectivity is the degree to which a landscape facilitates or impedes the movement of individuals or flows of energy or matter between habitat patches. [6, 8] There are two main ways of looking at connectivity:

1) **structural** connectedness of the landscape is the degree to which habitat patches are physically linked;
2) **functional** connectivity is dependant on species dispersal abilities, the size and spatial arrangement of habitat patches and the nature of land cover and land use in the intervening matrix. The same landscape can be functionally connected for one species but not for another.

Investigating the evidence that landscape features affect connectivity

Although supported by ecological theory,[9] evidence of a relationship between particular landscape features and connectivity has appeared limited and equivocal. [10, 11] In the context of developing policy on adaptation to climate change there is a need to reconsider the scientific evidence and the degree to which this supports the promotion of habitat connectivity as a response to rapid climate change. [6]

A systematic literature review (Box 1) and expert consultation was therefore carried out to examine the strength of the evidence for a link between landscape features and connectivity, including UK BAP priority species.[12]

Box 1: Systematic review of the evidence

Systematic review is a tool used to collate, summarise, appraise and communicate the results and implications of a large quantity of research and information both published and un-published. It can support decision-making by providing an independent and objective assessment of evidence. [13] This systematic review of connectivity synthesised the available world-wide evidence including database and internet searches, meta-analysis[14] of relevant quantitative datasets and exploration of qualitative data. In consultation with the project steering group, priority was given to assessing evidence that landscape features, particularly those between habitat patches such as corridors and matrix structure, can enhance connectivity and species movement. A total of 11,270 documents were systematically assessed and 313 studies (all on animals) identified where direct measurement of species movement had been undertaken in relation to the presence/absence of corridors or to the structure of the intervening matrix between habitat patches. A qualitative review was undertaken on a subset of studies concerning UK species (67 studies; 109 species; 18 UK BAP priority species; 9 non-native species).

Connectivity is affected by the presence of corridors and permeable matrix

The meta-analysis was suitably robust to provide evidence that corridors facilitate movement between habitat patches and that matrix types similar to the organism's "home" or breeding habitat patch are more permeable to species movement than structurally dissimilar matrices. However, there is a high degree of uncertainty associated with the interpretation and most studies were very small scale. Furthermore there have been no direct comparisons of the choice between providing a corridor, as opposed to a permeable matrix, on species movement.

Some UK species benefit from increased connectivity

The qualitative analysis focused on 67 studies of UK species, most of which considered butterflies and moths, birds, ground beetles and rodents (Annex 1). Freshwater invertebrates appear particularly under-investigated and there were no studies on UK reptiles. Spatial scale of the studies ranged from 0.03 m^2 (natterjack toads) to 15,800 km^2 (deer) and timescales from two minutes to five years. Positive responses to intervening matrix features of a similar structure to the 'home' habitat were recorded across taxonomic groupings, habitat types and scales (Box 2). Exceptions occurred where the species was highly mobile and did not react to the matrix (e.g. the non-native grey squirrel), used more permeable features but still dispersed at the same rate, or used less structurally similar features for cover. Some negative responses (decreased movement or dispersal) to barriers such as roads were recorded (Box 2).

Implications of the review findings for policy and practice

The results of the systematic review suggest that there is some evidence, albeit partial and limited, that landscape features between habitat patches, such as corridors and matrix structure can have a role in enhancing connectivity. Relatively mobile groups like butterflies, birds and large herbivores benefit from increased connectivity. For these species, spatial targeting of measures to create corridors and a matrix with structural affinity to the "home" habitat should enhance population persistence and may promote longer distance movement. However, there was a large number of species for which no information was available; reptiles and species of freshwater habitats were particularly poorly covered as were species of low mobility. Plants were not included in the review as no plant studies fitted the strict inclusion criteria. For these species, the benefits of landscape modification to promote landscape connectivity remain unproven. In other instances the evidence was equivocal or confounded by other variables so that the relative importance of landscape features, compared to other factors which affect species movement, is unclear. Nevertheless, no evidence was found that contradicted current policy and practice (Box 3). **Given the magnitude of the threat posed by climate change, a precautionary approach would indicate that measures to enhance functional connectivity should be a priority.** It is suggested that such activities take place within the context of adaptive management at a scale matched to the need.

Box 2: Qualitative synthesis and tabulation of information from studies on UK species included within the systematic review. The effects of various landscape features on species movement are summarised.

Landscape feature	Description	Effect on species movement
Corridor	A physical, continuous, though not necessarily linear, linkage between habitat patches; often of the same vegetation type as the habitat patches but not capable of supporting a breeding population	Positive outcomes reported (e.g. peregrin falcons, butterflies, bush crickets), although there were few studies
Man-made barriers	A linear, 'hard engineering' feature e.g. road, weir, or a structure built specifically to overcome that feature e.g. tunnel	Negative impacts reported for roads particularly larger/multiple roads. Tunnels were often avoided; the type preferred depending on the species. Weirs had a negative impact
Linear permeable	Any linear feature used as a movement route as opposed to a barrier (e.g. hedge)	Mostly positive outcomes reported over a range of studies. Some species seem to follow linear elements to navigate. This includes elements of dissimilar structure to their home habitat
Patch edge	Boundaries of the home habitat type.	Little evidence found in this review
Matrix - direct comparison (not including linear features)	Studies where two different kinds of matrix were compared in situations where other factors were controlled	Positive responses to matrix types more similar to the home habitat reported for butterflies and amphibians. Preferences may be based on protection from predation. Localised movement of mammals was less impacted by the matrix. Evidence for other invertebrates comprised a mixture of positive and neutral effects
Matrix - composition	Studies in which the amount of each land cover type in a landscape was tested but no account taken of how patches were arranged	Reports of animals making large-scale movements in response to the matrix, e.g. deer and birds. These movements may be related to resource availability
Matrix - heterogeneity	Studies examining the spatial arrangement of the matrix, most studies referring to the degree of fragmentation.	Less evidence of positive response. Deer and bush crickets moved further and were more likely to move in fragmented landscapes, possibly to find a less fragmented area

However, combating the impact of climate change on biodiversity cannot be addressed solely by improving connectivity. Intervention to increase species' resilience to climate change may be as important as measures to enhance movement. Actions that can promote resilient populations include: conserving protected areas and all other high quality habitats, reducing sources of harm not linked to climate, conserving the range and ecological variability of habitat and species, creating buffer zones around high quality habitats, and taking action to control spread of invasive species.[7] In turn, larger populations can produce more individuals capable of dispersal and habitats will be more welcoming to colonisation and establishment, thereby increasing the likelihood and success of chance, long-distance dispersal events which for many species appear to be vital in keeping pace with climate change. [5]

Box 3: Examples of current policy and practice aimed at enhancing connectivity

There is widespread agreement among policy stakeholders on the importance of developing ecological networks (and enhancing connectivity) as one of a suite of measures to help biodiversity adapt to climate change.[15, 16] A range of initiatives aimed at enhancing connectivity are on-going in the different UK countries. In Scotland, for example, Scottish Natural Heritage and Forestry Commission Scotland have been developing forest habitat networks[17] and lowland habitat networks.[18] In Wales, the Countryside Council for Wales and the South Wales Ecological Connectivity Group have initiated a project called "natural connections".[19] Natural England and partners have been involved in the planning of networks for lowland and chalk grassland species, and for the priority species such as the Adonis Blue butterfly.[20] These projects rely heavily on models such as BEETLE[9] and LARCH[21] which are based largely on ecological theory and the characterization of functional connectivity.

The need for further review and research

The systematic review was effective in structuring an analysis of very disparate evidence. However, due to time constraints and the need to have a tight focus on specific questions, the review covered a relatively narrow slice of the potential full range of evidence that could be brought to bear on the connectivity question. Taking a more broad brush approach would allow a wider set of questions to be considered, but this would inevitably lead to a less thorough and objective appraisal of available evidence.

Notwithstanding the need for immediate action based on available evidence, further research over longer time-scales and greater spatial scales is required to refine our understanding of the spatial and temporal patterns of use of landscape features by different species and taxa. Additional analysis of the literature gathered in the systematic review would help build a more complete picture, but there is a pressing need for studies of species movement relating to fragmented landscapes over wide spatial scales and longer time periods, and a need for further evaluation of the effectiveness of landscape interventions in controlled situations.

Endnotes

1 UK Biodiversity Partnership (2007) Conserving Biodiversity – The UK Approach. Published by the Department for Environment, Food and Rural Affairs on behalf of the UK Biodiversity Partnership.

2 Walmsley, C.A., Smithers, R.J., Berry, P.M., Harley, M., Stevenson, M.J. and Catchpole, R. & (Eds.). (2007) *MONARCH - Modelling Natural Resource Responses to Climate Change - a synthesis for biodiversity conservation* UKCIP, Oxford.

3 Opdam, P. and Wascher, D. (2004) Climate change meets habitat fragmentation: linking landscape and biogeographical scale level in research and conservation. *Biological Conservation* **117**: 285-297.

4 Pearson, R.G. and Dawson, T.P. (2005) Long-distance plant dispersal and habitat fragmentation: identifying conservation targets for spatial landscape planning under climate change. *Biological Conservation* **123**: 389-401.

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[6] Parliamentary Office of Science and Technology (2008) *Ecological Networks*. POSTNote 300. Parliamentary Office of Science and Technology, London.

[7] Hopkins, J.J, Allison, H.M., Walmsley, C.A., Gaywood, M. and Thurgate, G. (2007) *Conserving biodiversity in a changing climate*. UK Biodiversity Partnership. Defra, London. www.ukbap.org.uk/Library/BRIG/CBCCGuidance.pdf

[8] Lindenmayer, D.B. and Fischer, J. (2006) Habitat *Fragmentation and Landscape Change: An Ecological and Conservation Synthesis*. Island Press, Washington DC.

[9] Watts, K, Humphrey, J.W., Griffiths, M., Quine, C. and Ray, D. (2005) *Evaluating biodiversity in fragmented landscapes: principles*. Forestry Commission Information Note 73. Forestry Commission, Edinburgh.

[10] Davies, Z.G. and Pullin, A.S. (2007) Are hedgerows effective corridors between fragments of woodland habitat? An evidence-based approach. *Landscape Ecology* **22**: 333-351

[11] Bailey, S. (2007) Increasing connectivity in fragmented landscapes: An investigation of evidence for biodiversity gain in woodlands. *Forest Ecology and Management* **238**: 7-23

[12] Eycott, A., Watts, K., Brandt, G., Buyung-Ali, L. Bowler, D., Stewart, G. and Pullin, A. (2008) *What is the evidence for the development of connectivity to improve species movement, as an adaptation to climate change?* Unpublished contract report to Defra. Defra Contract CR0389. Forest Research, Roslin, Centre for Evidence-Based Conservation, Bangor.

[13] Pullin, A.S. and Stewart, G.B. (2006) Guidelines for systematic review in conservation and environmental management. *Conservation Biology* 20: 1647-1656

[14] Meta-analysis is a statistical technique used within a systematic review to integrate and summarise the results from individual studies providing greater statistical power, and allowing comparison of studies yielding contrasting results.

[15] The Woodland Trust (2006) *Adapt or die? Climate change and woodland.* The Woodland Trust, Grantham.

[16] The Scottish Executive (2006) *Scotland's Biodiversity – It's in your hands*. Scottish Executive, Edinburgh.

[17] Humphrey, J., Ray, D., Watts, K., Brown, C., Poulsom, L., Griffiths, M. Broome, A. (2004) *Balancing upland and woodland strategic priorities*. Scottish Natural Heritage Commissioned Report No. 037 (ROAME No. F02AA101). Scottish Natural Heritage, Edinburgh.

[18] Humphrey, J., Watts, K., McCracken, D., Shepherd, N., Sing, L., Poulsom, L. and Ray, D. (2005) *A review of approaches to developing Lowland Habitat Networks in Scotland*. Scottish Natural Heritage Commissioned Report No. 104 (ROAME No. F02AA102/2). Scottish Natural Heritage, Edinburgh.

[19] www.ccw.gov.uk

[20] Branch Partnership (2007) *Planning for biodiversity in a changing climate*. Branch Project Report, Natural England, UK.

[21] Koolstra, B.J.H. (2000) LARCH: a computer model to assess fragmentation of landscape. In J. Carsjens (ed.), *Fragmentation and land use planning: analysis and beyond; proceedings*. Wageningen, ISOMUL/WU, pp. 33-34. Alterra, Netherlands.

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Annex 1. List of BAP priority species and non-native UK species included in papers subject to qualitative synthesis in the systematic review.

Native species	**Non-native species**
Arvicola terrestris (Water vole)	*Abax parallelus* (a carabid beetle)
Asilus crabroniformis (Hornet robberfly)	*Branta canadensis* (Canada goose)
Bufo calamita (Natterjack toad)	*Bucephala clangula* (Goldeneye)
Chrysolina graminis (Tansy beetle)	*Cervus nippon* (Sika deer)
Emberiza schoeniclus (Reed bunting)	*Oncorhynchus mykiss* (Rainbow trout)
Erinaceus europaeus (Hedgehog)	*Oryctolagus cuniculus* (European rabbit)
Fabriciana adippe (High brown fritillary)	*Pacifastacus leniusculus* (Signal crayfish)
Lepus europaeus (Brown hare)	*Rattus norvegicus* (Brown rat)
Melitaea athalia (heath fritillary)	*Sciurus carolinensis* (Grey squirrel)
Melitaea cinxia (Glanville fritillary)	
Muscardinus avellanarius (Hazel dormouse)	
Mustela putorius (Polecat)	
Parus montanus (Willow tit)	
Parus palustris (Marsh tit)	
Salmo trutta (brown trout)	
Sciurus vulgaris (Red squirrel)	
Triturus cristatus (Great crested newt)	
Tyria jacobaeae (Cinnabar moth)	