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ECOLOGICAL NETWORKS

Ecological networks are intended to maintain environmental processes and to help to conserve biodiversity where remnants of semi-natural habitat have become fragmented and isolated. This POSTnote considers the possible conservation benefits of ecological network implementation in the UK.

Background.

Human impacts on landscapes in the UK over the last century have adversely affected biodiversity. There has been a substantial reduction in the total area of many semi-natural habitats, especially in lowland areas, such as loss of woodland (POSTnote 275). In addition to this loss and resulting habitat fragmentation, there has also been an ongoing process of land use intensification from agriculture (POSTnote 254) and urbanisation. Small and isolated patches of semi-natural habitat within intensively used landscapes have become more vulnerable to damaging events and degradation, and any species they contain are unable to migrate between them.

Ecological Networks

There are a wide range of different approaches to creating ecological networks in Europe.[1] Although ill defined,[2] these generally allocate specific functions to different areas depending on their ecological value and nature conservation potential: [3]

- core areas, where the conservation of biodiversity, including habitats, is the key function
- movement routes, which allow species to travel between core areas – these may take the form of 'linear corridors' (physical links), 'stepping stones' (in between islands of semi-natural habitat) or 'permeable areas' (with some semi-natural features and/or a sufficiently low intensity of land use)
- buffer zones, which are adjacent to and protect the network from damaging impacts arising from human activities (such as nutrient enrichment from fertiliser drift).

There are now around 250 ecological networks globally. In 1995, 53 European countries agreed to the establishment of the Pan-European Ecological Network (PEEN). The European Centre for Nature Conservation (ECNC) coordinates this work in collaboration with the Council of Europe. Forty-two national and regional ecological network initiatives have now been developed across Europe, but are at varying stages of implementation.

In the UK, the countryside and nature conservation agencies and the Joint Nature Conservation Committee (JNCC)[4] are co-ordinating advice to the government and devolved administrations on a pan-UK national ecological network. Ecological networks have already been defined for England, Scotland and Wales. These are intended to deliver statutory European obligations (the Natura 2000 protected areas designated under the Birds (EC 79/409) and Habitats (EC 92/43) Directives), to enable cross border working and to provide a basis for PEEN engagement. Several regional ecological networks are also at various stages of development and implementation in the UK, including a well-established local initiative by Cheshire County Council (Box 1).

Box 1 Cheshire regional ECOnet

The Cheshire ECOnet project is being led by Cheshire County Council Environmental Planning Service with the support and involvement of a wide range of rural agencies, landowners and farmers, community groups and individuals. The development framework for the project was derived from a 1999-2003 EU funded Life ECOnet Project. By 2020 the Ecological Network for Cheshire will encompass nearly 4,000 hectares of new and restored peatlands, heathlands, woodlands, meadows and wetlands. The sandstone ridge between Frodsham and Bickerton has been chosen as the first of three five year implementation phases of the network (2005 -2010). This contains a potential chain of interconnected woodland networks, alternating with two interconnected heathland networks and two isolated peatland networks. It includes 14 Sites of Special Scientific Interest (SSSIs), 74 Sites of Biological Importance, 78 meres and mosses (wetland areas), and 28 ancient woodlands. The £3 million programme will be delivered through the Sandstone Ridge ECOnet Partnership (SREP).

Scientific Basis

Ecological networks are based on understandings arising from key ecological theories (Box 2). Despite the theoretical base for network design, the evidence base for the beneficial effects of networks is limited to a few or single species. [5] Most ecological networks are under development and have not progressed to the stage where beneficial conservation outcomes can be shown[2] and to do this will require decades of monitoring.[3]

Connectivity

Connectivity is the degree to which a landscape facilitates or impedes the movement of individuals or flows of energy or matter between habitat patches (Box 2). There are two theoretical components:

- different landscape elements and habitat patches and their arrangement. These will create a mosaic of features that can either hinder or enhance movement (structural connectedness)
- the ability of species to move through a landscape mosaic (Box 3). This will depend on various specific traits, such as dispersal, movement and colonisation abilities and dependence on specific habitat features (functional connectivity).[6]

Box 2 Theoretical basis for Ecological Networks

Landscape Habitat Patches

In some modelling approaches, landscapes comprise a mosaic of habitats and other patches, each type of patch having its own characteristics.[7] Patches often have discrete shape and spatial configuration, and can be recognised by specific combinations of plants and animals that can be related to particular physical features, e.g. unimproved limestone grassland. The structure, arrangement and management of patches in a landscape (the matrix) has an effect on ecological processes, such as seed and animal dispersal, nutrient cycling, water availability and wind exposure. This influences organisms' movement abilities.

Edge Effects

Influences from adjacent land use can cause an environmental difference between the edge of a patch and its interior. This edge effect can change species composition, and result in, for example, scrub vegetation at the edge of woodland where it abuts a grassland habitat patch. Habitat patches can become so small that they are dominated by these edge communities. Such patches may provide insufficient resources for some 'interior' species or support only small populations that are not viable in the long term. Nonetheless, edge habitats and transitions can be valuable features for nature conservation and may encourage dispersal between habitat patches.

Island Biogeography and Metapopulation Dynamics

The number of species found on an 'island' is determined by the balance between the rate at which new species colonise the 'island' and the rate at which species become extinct. Thus, 'islands' closer to the 'mainland' tend to have higher numbers of species due to higher rates of immigration, and larger 'islands' with larger populations of species will have lower extinction rates than smaller 'islands'. The conclusion that larger 'islands' closer to the 'mainland' tend to maintain higher levels of biodiversity can be applied to patches of habitat and networks.[8] In addition, ecological theory predicts that rates of species persistence will increase if habitats are large (as conditions are more likely to be stable), as round as possible (to reduce patch edge effects) and functionally connected to a network of similar habitats (to ensure exchange and re-colonisation).[9]

Increasing connectivity to enable the movement of plants and animals between otherwise isolated habitat patches is thought to sustain populations (Box 2). However, data on the abilities required for species to move through landscapes are limited and are likely to remain so. Some studies suggest that one effective means of meeting a range of species connectivity requirements across highly fragmented landscapes is by reducing the overall land use intensity and either improving the quality or size of remaining semi-natural habitat patches.[5,10,11] For example, the national UK ecological networks have sought to identify clusters of patches that might be functionally connected so that areas of land between such patches can then be managed accordingly.[12]

Box 3 The Silver-Spotted Skipper Butterfly[13]

The silver-spotted butterfly's preferred habitats are short turfed chalk grassland containing the species' sole larval host plant, sheep's fescue grass. The butterfly is a priority species for the UK Biodiversity Action Plan. In the past in the UK, it was widely distributed across southern and eastern England. However, as a result of land use changes, its distribution contracted to fewer than 70 small populations by 1982. Between 1982 and 2000, new areas of suitable habitat for colonisation emerged, due to land management changes, the recovery in rabbit populations and climate change expanding the microclimate range of the species. The number of populations grew from 68 to 257 and the area of occupied habitat rose 10-fold. Colonisations occurred only over short distances, and over 80% of suitable habitat patches between 5 and 15km from the original 1982 population sites remained uncolonised, and over 90% of new populations established since 1991 were within 5km of the 1991 distribution. There were no direct colonisations when habitats were more than 9 kilometres apart, although a long distance colonisation of 29km from a 1982 site occurred through a number of smaller 'stepping stone' colonisations between neighbouring habitat patches.

Issues

Evidence Base Requirements

There is debate about the extent to which establishing ecological networks will improve the long-term persistence of species populations in fragmented landscapes that are subjected to significant environmental change. [2, 10,14] There is evidence that habitat patches that are connected within a fragmented landscape have higher levels of biodiversity than those that are not,[15] indicating that existing connections should be maintained at least on a precautionary basis. However, there are difficulties in attributing species loss to reduced connectivity. Although the theoretical impact of increased isolation is understood, specific evidence for habitats and species within the UK is limited. Some studies suggest fragmentation has a very small impact on biodiversity compared with initial habitat loss, though the process is likely to be gradual and difficult to detect with so many other impacts occurring..[10] However, it is likely to intensify with projected climate change.

Species will move across different landscapes at different rates depending on the range of features present and the intensity of land use. Species also have different spatial requirements for connectivity depending on various species specific traits. Many mobile species, such as birds and bats, will have very different requirements from more sedentary specialist species with exacting habitat requirements. For example, many species unique to ancient woodland fragments have not colonised adjacent planted woodland, even after a period of 300 years.[16] By contrast, some bird, mammal and insect species that are currently at their northern limit of distribution within the UK, are expanding their range northwards and on to higher ground in response to recent climatic change.[17]

Climate Change and Habitat Fragmentation

Different species will respond differently to climate change (Box 4), but it is likely that many species will need to change their current distributions to new sites and areas with suitable climatic conditions. The potential impact of climate change on the location of such areas for species in the UK has been assessed through the Modelling Natural Resource Responses to Climate Change (MONARCH) project, which examined 32 representative species found in 12 different habitats.[18] This showed that some northern and upland species may experience reduced climate space, to the extent that some may disappear from the UK entirely. In contrast, many southern species see increases in areas of suitable climate conditions.

Box 4 Impacts of Climate Change on Biodiversity

Rising temperatures, changing rainfall patterns and other aspects of climate change are starting to have an impact on biodiversity in the UK. The range and abundance of many species will change, a process that has already been documented for many species. Research studies have shown that climate induced changes include:

- changes in the timings of seasons, which are getting earlier by 2.3 days per decade. This may lead to loss of synchrony between species, such as the availability of a food source during a species breeding season
- changes in species distribution and abundance within their existing habitats (including arrival of non-native species and potentially a loss of species for which suitable climate conditions disappear)
- changes in community composition, such that new combinations of species may occupy habitats
- changes in ecosystem function, such as changes to water table levels, higher vegetation growth rates or increased rates of decomposition in bogs
- loss of physical space due to sea level rise and increased storminess.

A recent assessment for Defra[19] found that of the 32 priority habitats in the UK Biodiversity Action Plan, seven were assessed to be at high risk from the direct impacts of climate change; mountain habitats, standing waters, floodplain and grazing marsh, saltmarsh, maritime cliffs and slopes, saline lagoons and open seas. A further 14 were assessed to be at medium risk and 11 at comparatively low risk or medium low risk. There are also likely to be indirect impacts from changes in land and natural resource use. These include changes in agricultural patterns such as crop types or crop management, changes in water resources, catchment management and coastal defences.

To help to accommodate the climate impacts on biodiversity set out in Box 4, the UK Biodiversity Partnership[20] has suggested that "ecological networks should be established and strengthened by programmes of habitat restoration and creation to improve opportunities for dispersal across landscapes and between regions in response to climate change".[21] In most cases, improving the quality, size and connections of remaining patches of semi-natural habitat through networks at a local, as opposed to regional, level should be sufficient to buffer the effects of climate change.[12]

Natural England has supported a research project demonstrating how ecological networks might be integrated into land use planning as a climate adaptation measure in Kent.[22] Other work is also being undertaken to determine the role of ecological networks in climate change adaptation in four pilot areas.

A Precautionary Approach

The modelling of large scale climatic changes does not consider the wide range of other factors that determine the abundance and distribution of species. However, it is clear that large scale connectivity approaches will need to be implemented in response to biodiversity loss under predicted climate change scenarios.[21] There is broad consensus on the urgent need for a better understanding of connectivity, including how and where to achieve it.[7]

Efforts to enhance connectivity need to be on a precautionary basis to address scientific uncertainties and risks (Box 5). This would include monitoring schemes to measure the effectiveness of the ecological networks and other connectivity measures in relation to specific and quantifiable biodiversity and ecosystem service (POSTnote 281) objectives. Consideration should be given to:

- protecting remaining semi-natural habitat features, increasing the size of small habitat patches, and maximising habitat condition through appropriate management
- reductions in land use intensity and protecting remaining semi-natural habitat features (through agri-environment schemes) may maintain functional connectivity across landscapes for many species[5,10,11]
- the inability of some species to migrate to suitable habitat, leading to local or even national extinction as a result of climate change.[23] For a minority of such species, it may be feasible to undertake wholesale translocation to suitable habitat.

Box 5 Ecological network design

In a detailed review undertaken on behalf of the EU[5], the Institute for European Environmental Policy (IEEP) suggested a precautionary approach, including:

- highest priority being given to maintaining, expanding and enhancing existing areas of key habitats
- a clear need and biodiversity and conservation objectives for any network implemented, including identification of the species that will benefit most from the ecological network
- increasing ecological connectivity by improving the overall ecological quality of the landscape matrix as well as physical linkages such as linear corridors (i.e. rivers) or stepping stones of small patches of habitats (i.e. woodlands)
- promotion of wildlife-friendly management of connective elements within the landscape such as hedgerows and ditches, including reductions in the use of fertilisers and pesticides
- Implementation of aspects of ecological networks through existing EU regulations and management measures such as the Water Framework Directive, Forest strategies, Agri-environment schemes and Integrated Coastal Zone Planning.

Modelling Ecological Connectivity

There are difficulties in accurately modelling the dispersal potential of the vast array of UK's plants and animals. A recent review carried out for the UK Biodiversity Action Plan suggests that the basic dispersal abilities are known for only a few species. There are significant uncertainties and data gaps in relation to:

- the complexity of the interactions between species and specific landscape elements at different scales
- the variation in species dispersal abilities by moving through fragmented landscapes.

A generic species concept can be used for modelling. This is usually derived from the movement abilities of a range of species with contrasting requirements and varying dispersal abilities associated with the given habitat type.[24] The Geographic Information System (GIS) modelling for the UK network predicts where some form of connectivity between habitats might exist using the generic approach, on the basis of limited available data and expert judgement to estimate the permeability of different landscape matrices and current patterns of connectivity (Box 6). This has the advantage that conflicting management requirements will not be created between species. However, in the absence of detailed species and habitat data, models will lack predictive power and accuracy.[10]

Box 6 GIS modelling of connectivity

Geographic Information System (GIS) tools are computer based systems that are designed to store, retrieve, analyse, model and map large volumes of spatial data. Layers of biodiversity information can be overlain on maps to reveal key areas for connectivity. The modelling identifies key areas for habitat protection, management, restoration and re-creation/creation within possible ecological networks.[12] This approach has formed the basis for a pan-UK network. The information for England and Wales has been released as digital maps to inform land use planning and conservation activities.

A GIS -based decision support tool, Biological and Evaluation Tools for Landscape Ecology (BEETLE), is also being used by the Forestry Commission to develop patches of woodland and associated semi-natural habitats into ecological networks in Wales, Scotland and southwest England. This model uses the current distribution of habitat patches and the nature of the intervening land cover to define ecological networks (least cost analysis). The mapped Forest Habitat Networks are being used to target conservation action and payments to landowners to restore and improve existing woodland or to undertake new planting to create forest habitat networks that have the optimal landscape configurations for key species. For example in Glen Affric in Scotland, the 'Highland Locational Premium Grant' is being used to encourage expansion of pine and birch woodland towards a configuration that optimises habitat networks for both woodland and open ground species of conservation concern. BEETLE will also be distributed in Scotland as a tool for the development of lowland habitat networks through stakeholder groups.[25]

Risks of Increased Connectivity

There are also some risks arising from any large scale increases in connectivity.[5] For example, increasing connectivity in a river containing non-native signal crayfish could lead to the extinction of the native white-clawed crayfish through disease transmission. Other risks include:

- loss of locally adapted plants and animals that develop naturally in fragmented populations of some species
- the movement of invasive non-native species and wildlife diseases
- conflict between the connectivity requirements of different habitat types. For example, increasing woodland cover can act as a barrier to the dispersal of grassland species
- increased predation of species of conservation concern.

Overview

- Ecological networks are intended help conserve biodiversity where patches of semi-natural habitat have become isolated within intensively used landscapes. In addition, enhanced connectivity could buffer the effects of climate change on biodiversity.
- A pan-UK ecological network is being developed as well as regional networks.
- There are risks and scientific uncertainties in relation to increasing species connectivity through networks. A scientific evidence base needs to be developed from studies of ecological connectivity to determine effective and risk-assessed approaches.

Endnotes

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POST is grateful to all contributors and reviewers of this POSTnote. For further information on this subject, please contact Dr Jonathan Wentworth at POST.

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