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Planning for biodiversity – opportunity mapping and habitat networks in practice: a technical guide

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Summary

This work has been undertaken to try and provide a **bridge between science and practice**. It has attempted to demonstrate how first principles might be applied to existing information in order to try and deliver a consistent starting point for the integration of landscape ecological thinking in regional and local spatial planning. The approaches are not intended as substitutes for site-based conservation activity but represent an attempt to place sites in a wider, ecological context. This work has demonstrated where site context might need to be maintained or enhanced and has also established the utility of larger scale, strategic frameworks. These frameworks have formed the basis for the environmental sections of a number of **Regional Spatial Strategies** (RSS). Although the author has been involved in the application of similar methods across a number of different regions, this report just focuses on the Yorkshire and Humber region for the sake of brevity. Two distinct approaches have been developed.

The **first approach** utilised a **landscape characterisation framework,** consisting of landscape description units, which allowed environmental objectives to be set across entire regional land areas, not just for those areas rich in biodiversity. In doing this it has supported the Government's primary planning purpose of enabling sustainable development opportunities instead of restricting the potential activity to conservation-led initiatives. The approach was also selected to provide a common geography through which a range of cultural and historical information might also be expressed. However, as the main purpose of the work was to provide an environmental summary, habitat inventory information was used as the main input. More specifically the density of UKBAP priority habitats within each unit was calculated to provide the basis for a thematic map. After validation by local stakeholders, a number of different environmental objectives were set for each category. These framed appropriate actions for delivery of environmental gains. For example, the development of terrestrial habitat networks in areas with little remnant semi-natural habitat is likely to be neither effective nor practical. Environmental planning in these areas should focus on other objectives such as the delivery of critical 'goods and services', eg flood prevention. The same method has been promoted in a number of other regions and has since been submitted as part of the draft North West RSS (January 2006) and recommended for inclusion (after completing an Examination in Public) in the East of England RSS (June 2006). It has also been submitted as part of the draft Yorkshire and Humber RSS (December 2005).

The **second approach** directly evaluated the **degree of connectivity between existing patches** of habitat by making an assumption about the relative cost to movement across different types of land cover. This approach was based on a functional analysis of the potential for the movement of individuals between sites. The approach had nothing to do with physical linkage or corridors. A series of indicative maps, at different scales, were produced that enabled users to identify which areas of landscape might enhance or inhibit the movement of individuals. The approach explicitly supports local decision making by allowing users to 'retro-fit' species of local conservation interest. After appropriate local testing, these maps can be used to support the development of tailored action plans that seek to maintain and enhance the current wildlife resource across a wider network of sites. The outputs will form the basis of some supplementary planning guidance that will help to inform Local Development Frameworks and Green Infrastructure planning across the Yorkshire and Humber region. The same method has been applied across the West Midlands region where its potential application is being considered by a number of local stakeholders. It has also

been applied across the whole of Wales and Scotland. The analysis will shortly be applied across the whole of England as a contribution to the development of a **national ecological network** for the UK.

These geographically explicit products have been produced to **empower local decision makers** who might not have access to the information or expertise they need to make informed judgements about the conservation choices beyond designated sites. It is expected that the products will be subject to considerable local testing and refinement as they rely on national data which have obvious limitations when compared with some more detailed local data sources. However, it should be noted that the information that has been used is, in most instances, the only source of data available at a regional scale. In all cases modified national habitat inventory data were used that had been aggregated into broad biotopes and subject to extensive 'cleaning'. One advantage to the use of this information has been that the products detailed in this report can now be readily generated, at minimal cost, for any region in England. The approach has been specifically developed in order to **promote an 'information equality'** amongst local stakeholders. It does not rely on the imposition of fixed blueprints, an extensive network of local experts, established biodiversity partnerships or expensive project officer funding.

English Nature believes that the approaches that have been described have clear potential to provide a direct and pragmatic contribution to the definition and delivery of Regional Spatial Strategies, Local Development Frameworks, Green Infrastructure, CBD 'ecosystem approach', Local Biodiversity Action targeting and in the longer term, agri-environment targeting. The outputs from the connectivity analysis, in particular, may have significant potential to deliver realistic **climate change adaptation** if considered in combination with flexible conservation objectives and adaptive management techniques. The outputs from this analysis will also provide a credible basis for the delivery of both national (eg PPS9) and international (eg Habitats Directive, Pan-European Ecological Network) obligations to develop habitat networks. No other work has been done at the regional scale, with the exception of the West Midlands and Yorkshire and Humber regions, that is able to meet such obligations. English Nature believes that the application of a consistent approach to the definition of functional habitat networks for terrestrial and riverine habitats must be developed to meet these obligations and better inform local activity such as Green Infrastructure Planning and Local Development Frameworks.

This work recognises the shifting agenda for conservation in England that is associated with the creation of Natural England and has the potential to inform a number of emerging priorities. For example, it demonstrates the benefits of common geographies, defines key areas for extensification and low intensity land management, links protected areas with their wider landscape, helps to frame sustainable development objectives at different scales and provides a credible basis for climate change adaptation.

Contents

1 Introduction

This guide has been designed to bring together the **technical background** and justification for a number of spatially explicit, approaches that have been used to evaluate key habitats across a number of regions in England. This guide has been designed to help set strategic objectives that will complement existing site-based conservation activities. It is not intended as a substitute for site-based conservation nor should it be used as a fixed blueprint. Rather it should be viewed as a starting point for defining local action; a framework for local decision support rather than another layer of designation or constraint. It has been specifically designed to support the delivery of statutory obligations as well as a number of international agreements in an ecologically robust, transparent and justifiable manner. It has the potential to inform regional climate change adaptation strategies in a direct and tangible way. The provision of functional networks will be critical for improving resilience of the environment for future generations. It is a planned response that will help to sustain biodiversity in the longer term.

The main emphasis of this work has been pragmatism and local empowerment. The pragmatism arises from the need to use currently available information in a cost effective manner and the empowerment arises from the need to support local decision making processes. These are mutually beneficial. For example, evaluation at larger scales provides a strategic context for local action while local validation and refinement helps to deal with uncertainty. Uncertainty is especially problematic when working at larger scales. This can arise from a number of sources. The most common is related to the availability and accuracy of information. In spite of a long tradition of natural history recording, information on the location of key biodiversity assets is still limited at larger scales. This can be seen in figure 1 which shows the capture of full resolution records at a national level.

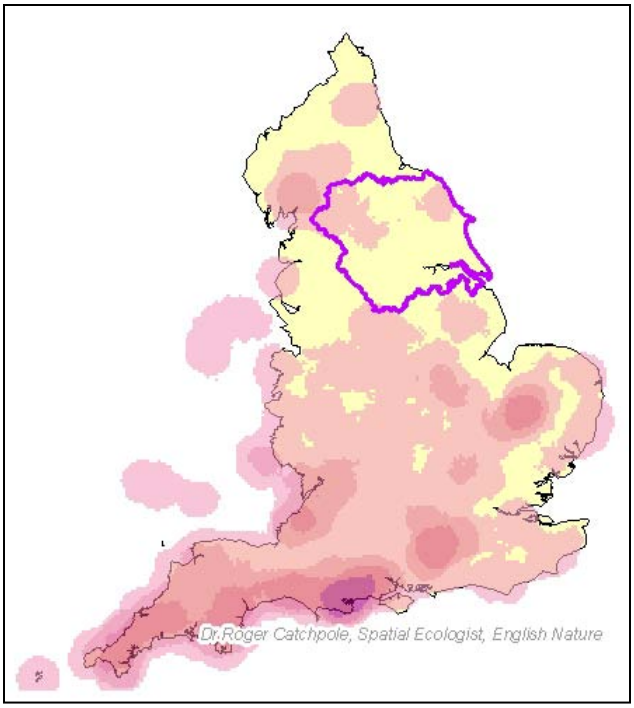

Figure 1: Density of full resolution records for species taken from the threatened plant database, threatened bryophyte database, national biodiversity network database and the biological records centre at Monkswood. Only UKBAP priority species were included from the latter two databases.

This was produced from information that was obtained from a number of different information sources in 2004. Records of a suitable resolution were extracted from the threatened plant database, threatened bryophyte database, national biodiversity network database and the biological records centre at Monkswood. It should be noted that records from the last two sources only consisted of UKBAP priority species (HMSO, 1995). When the extent of statutory sites and priority habitats are considered, the limitations of this information became apparent. This is because it can be assumed that many of the sites will support such species even though no records are present, see figure 2.

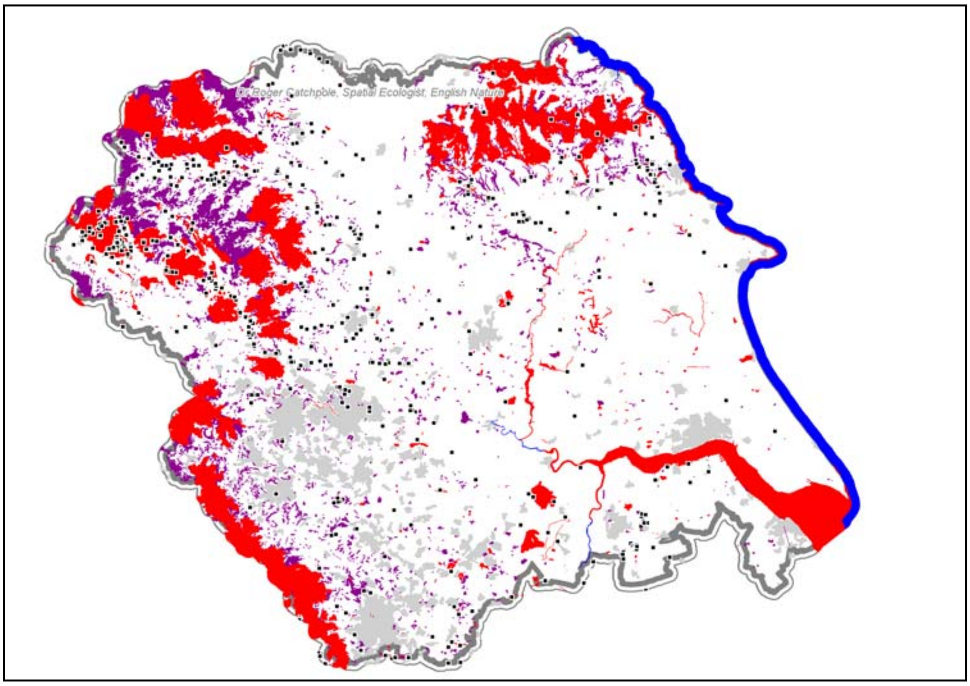

Figure 2: Species records and the distribution of sites across the Yorkshire and Humber Government Region. Statutory habitat is shown in red, non-statutory UKBAP priority habitat is shown in purple and species records as black dots.

Some of this lack of correspondence will be due to the fact that many records are supplied at a much lower resolution, eg 10km squares, and some of it will be due to the fact that the information is simply not made more widely available. Although this situation is improving, through the work of the National Biodiversity Network, significant omissions remain. Any implementation strategy that is based on species distribution data alone will always risk significant under-representation. This is why the main approaches that have been outlined in this document are based on the distribution of habitat rather than the distribution of species. The relevance of the results to individual species can still be considered, however, through other work that has attempted to associate UKBAP habitats to species (Simonson and Thomas, 1999). Although information on the location of habitats can generally be considered more reliable because of its greater accessibility, there are clearly similar issues in relation to variation in recorder effort which become apparent when more detailed local information is available. As a consequence, what follows **must** be treated as indicative and should always be subject to local refinement and validation. It provides some signposts, not a blueprint.

1.1 Issues

This section is intended to establish the evidence base to justify the need to work at larger scales, beyond the current protected areas system. Its length reflects an absence of any suitably referenced discussion in the wider conservation literature at the current time.

The impacts of widespread land use change are now making themselves felt across much of Western Europe (Bouma and others, 1998; Jongman and others, 2004). Fry and Gustavsson (1996) identify two broad patterns that have significant implications for the continued maintenance of biodiversity at broader scales: land use intensification and land abandonment. Although abandonment has been largely restricted to alpine and Mediterranean regions (Laiolo and others, 2004; Suárez-Seoanea and others, 2002), changes in agricultural subsidy may lead to a more widespread occurrence in the UK in the future. Land use intensification has been more widely observed and has been directly linked to the loss and fragmentation of semi-natural habitat (Jongman, 2004). This, in turn, has been considered by some authors as one of the most significant threats to biodiversity conservation worldwide (eg Bennett, 2003).

Over the last 65 years there has been an extensive loss of semi-natural habitat beyond protected areas in the UK which has been documented in a series of publications which have been described by some as a "grim litany of outrage and complaint" (Adams, 2003). For example, in South Derbyshire, over 96% of semi-natural, non-statutory permanent grasslands were lost between 1983 and 1999 (Houston, per. com.). This represented a reduction in area from 875ha to just 40ha. In Lancashire, 494ha of lowland raised bog was reduced to just 11ha between 1948 and 1978 (NCC, 1984). In Dorset, there was a 40% loss of lowland heath between 1960 and 1978 which further reduced the area to just 20% of what had been present in 1811 (Moore, 1987). More generally by the mid-1980's only 4% of UK grasslands remained 'unimproved' by intensive agriculture (Fuller, 1987).

When habitat loss is coupled with large-scale environmental trends, such as climate change and eutrophication, the conservation of biodiversity at the level of the individual site and the wider landscape, becomes problematic. The UN Millennium Ecosystem Assessment (Sarukhán and Whyte, 2005) identifies a number of drivers that have been associated with biodiversity loss worldwide. It views the five most significant as: habitat change, climate change, eutrophication, invasive species and over-exploitation. The trends in these different drivers have been summarised in figure 3.

Although similar drivers are operating at both the European (EEA, 2003) and UK (Haines-Young and others, 2000) scales, little has been done to promote any integrated land management and land use planning solutions across England. With the possible exception of the Environmentally Sensitive Areas (ESA) scheme, much has been left to local discretion; often with highly variable results (see Saunders and Parfitt, 2005). Coherent responses to these broader environmental trends, that incorporate current ecological thinking and address strategic issues, are generally lacking and clearly need to be embedded in future initiatives.

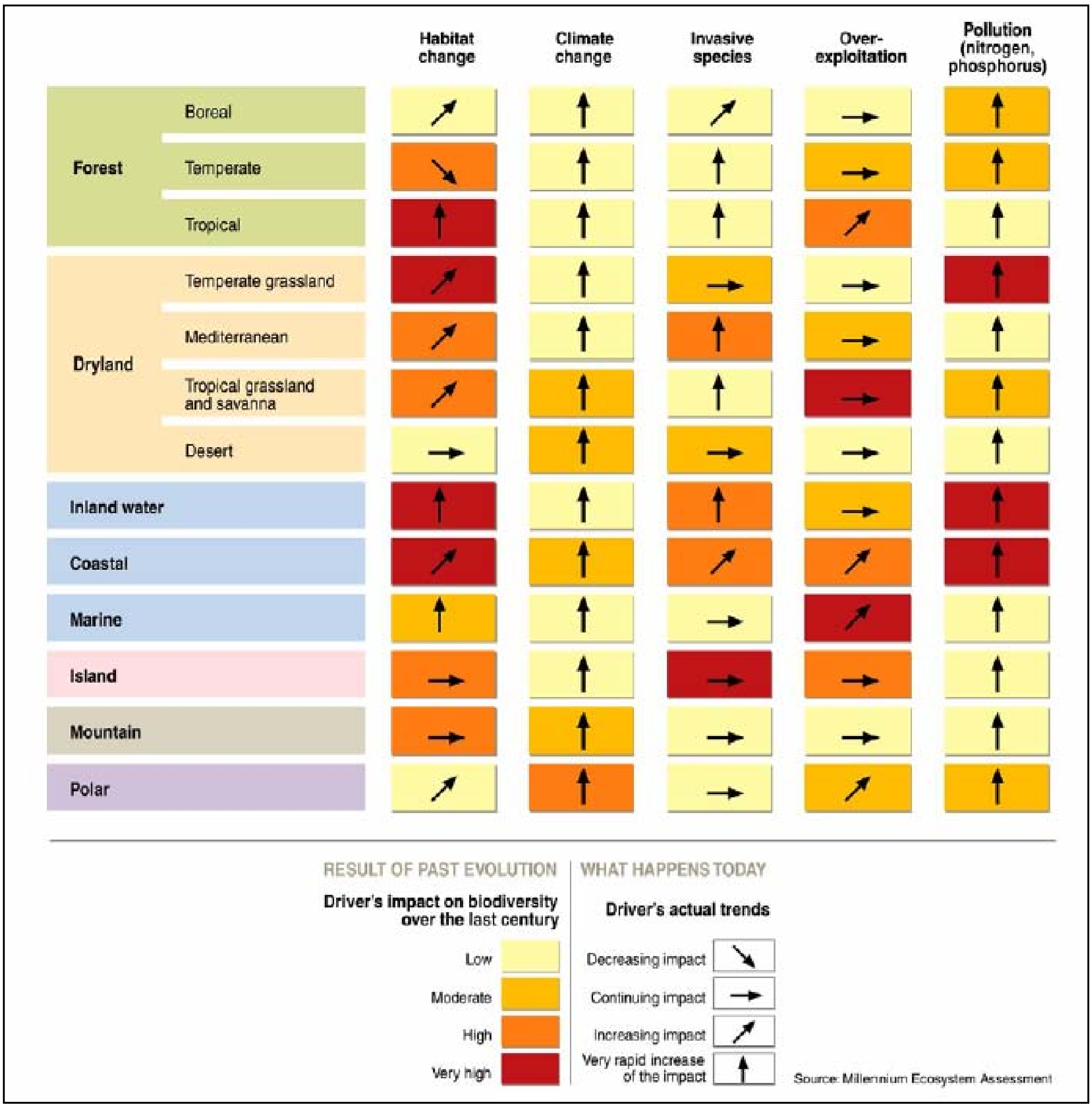

Figure 3: Millennium Ecosystem Assessment of trends in the impact of five main drivers on biodiversity loss.

One of the key issues facing many sites is the threat that these environmental drivers pose to an increasingly isolated and fragmented resource. As the remnant areas of semi-natural habitat in between sites has been lost, so the functional isolation of these areas will have increased over time. However, evidence suggests that the increase in isolation and the reduction in patch size that is caused by the loss and fragmentation of habitat are not the only factors that influence population persistence. Recent studies have emphasised the importance of both patch quality (Vebeylen and others, 2003) and patch context (Riffell and others, 2003) in addition to patch area (Mannechez and others, 2003) and patch isolation (Tischendorf and others, 2003). The most vulnerable sites might reasonably be identified as the smallest, most isolated, poor quality sites that occur in the most hostile land use context. When such sites are also experiencing negative environmental impacts, *e.g.* nutrient loading, hard decisions may need to be made. If a battlefield triage analogy is considered, then there are just three choices for a particular interest feature: leave it, manage it or move it. Although work is currently in progress to evaluate these factors in a systematic manner (Catchpole, 2005), the degree to which species that rely on such sites are "ecologically extinct" (Estes and others, 1989) is unclear at the current time. What is clear, however, is that current land use patterns and conservation activities are failing to maintain biodiversity.

The continued decline of a wide range of different species can be viewed as a symptom of a deeper underlying 'pathology' that remains largely untreated. For example, significant declines continue to be noted in woodland birds (Eaton and others, 2005), bumblebees (Kells and others, 2003; Goulson and others, 2006), vascular plants (Cheffings and others, 2005), woodland plants (Kirby and others, 2005), infertile grassland plants (Bunce and others, 1999), pollinators (Biesmeijer and others, 2006) and butterflies (Bergman, 2001; Fox and others, 2001; Swaay and others, 2006).

Why should any of this be of concern to the regional or local planning process? Leaving aside the legal duty outlined in section 40 of the Natural Environment and Rural Communities Act (2006); there is a very practical reason why this situation is not acceptable. Biodiversity is essential to the long-term provision of critical, ecosystem 'goods and services' to human beings and an essential component of sustainable development. These have been broadly defined as those functions that enable society to meet its future "goals and aspirations" (Rapport and Moll, 2000 p488) and more generally in relation to the 'quality of life' that society experiences (Troyer, 2002). Key services include processes such as flood prevention, aquifer re-charge, decomposition, pollination, climate regulation, nutrient cycling, detoxification of pollutants, hydrological cycling etc. Key goods include products such as food, clean water, clean air, medicines, recreation, education, tourism, improved health etc. More comprehensive reviews as well as some consideration of its potential application to land use planning can be found in a number of publications (eg de Groot and others, 2002; Daily, 2000; Daily, 1997).

Even though some goods and services might continue to be delivered with less biodiversity (Purvis and Hector, 2000), keeping as many species as possible is extremely important because: 1.) the limited knowledge that we will always have of ecosystem function means that it will never be possible to identify which species we can afford to lose; 2.) diverse ecosystems will provide the best insurance against future environmental change (Noss, 2000). A recent review of this issue identified a broad scientific consensus that the continued provision of most environmental goods and services, in the longer term, will only be delivered where biodiversity is maintained (Hooper and others, 2005). It should also be remembered that it is highly likely that unforeseen services may be provided that will only become apparent when an ecosystem collapses. A precautionary approach, that maintains biodiversity wherever it may occur, is the best policy to adopt.

2 Adapting to change

How can we move beyond the polarised, intensively managed landscapes that have become so widespread? Are there approaches that would lead to a more resilient environment that can adapt to change and still provide critical goods and services? Before these questions can be answered some definitions are needed.

Ecology attempts to understand processes at different levels of organisation, from individual molecules to the whole biosphere, ie the Earth (Krebs, 1985). Conservation activity in particular, and land management in general, typically only operate at the level of the population and community. In practical terms this usually equates to site-based management and development-led, constraint mapping. If issues of resilience and integrity are to be addressed then at least one other level needs to be considered: the ecosystem.

Since the concept of an ecosystem was first introduced (Tansley, 1935), it has been interpreted in a number of ways. Just two important characteristics need to be considered in the current context. Ecosystems are independent of scale and they encompass both physical and biological processes. A handful of soil or a decomposing log can clearly be considered an ecosystem as much as a whole forest or an estuary. Management on a large scale should not therefore be equated with ecosystem management. The spatial limits of individual processes clearly determine the location of such boundaries and will also determine how the integrity of an ecosystem might be measured.

In practice, if integrity is to be fully evaluated, then the flow of individuals, water, nutrients and energy all need to be explicitly considered. In the current context this evaluation has only extended to the flow of individuals which means that only a partial evaluation of integrity has been undertaken. Work is currently in progress to evaluate other processes in a more integrated and practical manner (Catchpole and James, 2006).

In spite of this limitation, the current approach still provides an indication of where the ecological integrity of the current biodiversity resource might be maintained or enhanced. As this has been based on an analysis that is both systematic and repeatable, it can not only be easily refined, as new information becomes available, but its assumptions can also be tested.

2.1 Habitat networks

One response to habitat fragmentation that has gained a significant foothold in land use planning over the last decade has been ecological networks (Jongman and Pungetti, 2004). They are grounded in work that attempted to divide landscapes into three basic elements: patch, corridor and matrix (Forman and Godron, 1981). This simplistic representation is most often applied through the quantification of landscape structure rather than ecological processes. In practice, it has been implemented in a number of different ways within a European context (Jongman and others, 2004). Three distinct responses have been described. The first (ecostabilisation) relies on allocating different land uses to specific areas, eg housing, industry, nature etc that are then physically linked to create a network. The second (riverine) relies on river corridors to provide a ready-made, physically linked network. The third (ecological) employs a range of different approaches, such as habitat suitability modelling, to define more functional networks.

In 1995 a significant number of European countries endorsed a plan to create a Pan-European Ecological Network (PEEN). The European Centre for Nature Conservation (ECNC) has subsequently attempted to bring together many of these approaches under a common framework. The explicit identification of core areas, corridors, stepping stones and buffer zones has been promoted and clearly has its origins in the work of Forman and Godron (1981). In a recent summary of progress on PEEN implementation it was reported that the UK will use a “countryside character approach” to develop an ecological network (Gilbert and others, 2005 p.36). While such approaches can make a significant contribution to strategic objective setting, English Nature does not support the use of character-based geographies as substitutes for the development of ecological networks. This is because the definition of ecological networks must be based on a direct evaluation of current connectivity between individual sites. Although such sites can be considered ‘core areas’ within the

PEEN framework, the definition of the other elements in England, Wales and Scotland differs from the PEEN model in that it is based on functional rather than physical linkage.

One aspect of the PEEN approach has been the focus of considerable debate in the ecological literature. Wildlife corridors have attracted the following comments:

"Corridors are an article of faith." (Hobbs and Hopkins, 1991);

"A remarkable publicity campaign, much of it outside the bounds of mainstream science, has promoted corridors for conservation." (Simberloff and others,1992);

"Despite decades of research, we do not know when and where corridors should be used to connect patches of habitat."
(August and others, 2002); and

"Evidence for the efficacy of corridors is nowhere near as compelling as the enthusiasm with which corridors have been embraced."
(Wiens, 2002).

Corridors have also had their supporters (Forman, 1991; Beier and Noss, 1998; Bennett, 1999). Although more recent work stresses the functional nature of corridors (eg Vos and others, 2002; de la Guerra and others, 2002), this subtlety is often lost when translated into policy and practice.

Even though considerable effort has gone into demonstrating the importance of linear features as conduits for movement (ie corridors), any such evidence can be considered largely irrelevant from a conservation perspective. Even if a number of species, that may or may not be of conservation interest, are shown to use linear features in this way, this does not mean that the creation and management of such features for this purpose is justified. The question is not whether species use linear features for movement but rather whether the physical linkage of habitat patches, at larger scales, is an effective conservation management tool. In spite of a continuing lack of evidence regarding their effectiveness once implemented (Vos and others, 2002), corridors remain deeply entrenched in both policy and legislation.

The broader interpretation of ecological networks that goes beyond physical linkage still remains valid however. Clearly some significant opportunities exist to embed such thinking in wider land use planning policy in England, eg green infrastructure planning (TCPA, 2004). Current guidance on green infrastructure planning relies on the adoption of a design-led approach to deliver "functioning ecosystems" (TCPA, 2004). The application of landscape architectural methods clearly does not lead to the systematic analysis of baseline ecological functions or provide a quantified basis for the definition of any enhancement areas. Any green infrastructure project that seeks to improve ecological function therefore needs to define the function(s) to be improved, evaluate its current state and identify areas to maintain, enhance and restore this function(s). The application of the methodology outlined in this report would significantly strengthen the ability of green infrastructure planning to deliver more credible environmental outcomes and address these issues.

In the current context, ecosystem function, in the form of functional habitat networks, has been defined by the potential for movement between existing habitat patches, across different land cover elements. The extent to which dispersal processes can be generalised in this way clearly still needs to be tested, but it offers a significant improvement in comparison to the existing approaches to green infrastructure etc. This method will also help to provide the consistent and credible delivery of a raft of other policies that are outlined in the next section. A fuller discussion of the importance of movement and the definition of connectivity can be found in annex 1.

2.2 Obligations

The need to develop habitat networks has been outlined in a number of international conventions and agreements that includes the Pan-European Biological and Landscape Diversity Strategy (1995); World Summit on Sustainable Development (Johannesburg, 2002); 5th EU Ministerial Conference (Kyiv, 2003); Objective 4, EU Biodiversity Stakeholders Conference (Malahide, 2004); and Article 10, Habitats Directive (1992). At a national level, relevant legislation and policies that stress the need to develop habitat networks can be found in Regulation 37, Conservation (Natural Habitats &c.) Regulations (1994); and Planning Policy Statement 9: Biodiversity and Geological Conservation (Office of the Deputy Prime Minister, 2005). Selected extracts can be viewed below:

> The Strategy sets out to achieve …. "1. Conservation, enhancement and restoration of key ecosystems, habitats, species and features of the landscape through the creation and effective management of the Pan-European Ecological Network." **Pan-European Biological and Landscape Diversity Strategy (1995).**

> Parties agree "to promote and support initiatives for hot spot areas and other areas essential for biodiversity and promote the development of national and regional ecological networks ……….. by 2012." **World Summit on Sustainable Development (Johannesburg, 2002).**

> "By 2006, the Pan-European Ecological Network …. in all States of the pan-European region will be identified and reflected on coherent indicative European maps, as a European contribution towards a global ecological network." and "By 2008, all core areas of the Pan-European Ecological Network will be adequately conserved and the Pan-European Ecological Network will give guidance to all major national, regional and international land use and planning policies as well as to the operations of relevant economic and financial sectors." **5th EU Ministerial Conference (Kyiv, 2003).**

> The Commission should ensure that … "the ecological connectivity of Natura2000 network is supported in order to achieve or maintain favourable conservation status of species and habitats in the face of climate change." **Objective 4, EU Biodiversity Stakeholders Conference (Malahide, 2004).**

> "Develop and apply instruments that contribute to achievement of conservation management goals through a combination of managing protected area networks, ecological networks and areas outside of such networks to meet both short-term and long-term requirements and conservation outcome in accordance with VII/28." **CBD Conference of Parties, VII (Kuala Lumpur, 2004).**

Member states will develop "…policies encouraging the management of features of the landscape which are of major importance for wild flora and fauna" such as "…stepping stones" and other features that are "…essential for the migration, dispersal and genetic exchange of wild species." **Article 10, Habitats Directive (Council Directive 92/43/EEC, 1992).**

"Networks of natural habitats provide a valuable resource. They can link sites of biodiversity importance and provide routes or stepping stones for the migration, dispersal and genetic exchange of species in the wider environment. Local authorities should aim to maintain networks by avoiding or repairing the fragmentation and isolation of natural habitats through policies in plans. Such networks should be protected from development, and, where possible, strengthened by or integrated within it." **Planning Policy Statement 9: Biodiversity and Geological Conservation (Office of the Deputy Prime Minister, 2005).**

Whilst important, many of these obligations also stress the use of physical corridors as a prescriptive method for delivering ecological networks. If a process-based approach is adopted, as discussed in the previous section and annex 1, then PPS9 becomes the most important reference point for justifying the development of habitat networks in England and Wales. It should also be noted that such an approach might also help to deliver other aspects of the Habitats Directive in addition to Article 10. More specifically:

Article 3(1) - Ecological coherence, under the terms of the Directive, is defined in Article 3 as a network of sites that enable the species and habitats that are listed in Annex I and II to be "maintained or, where appropriate, restored at a favourable conservation status in their natural range". The main aim of any implementation of Article 10 must consequently be focussed on the achievement of favourable conservation status (FCS) rather than just the management of specific landscape features.

Article 6(1) – Measures are required that integrate SACs with a wider land use planning context in order to meet the "ecological requirements of the natural habitat types in Annex I and the species in Annex II present on the sites". There is a clear requirement to move beyond constraint mapping and incorporate explicit ecological requirements in the spatial planning process. As one of the key requirements is movement, ie migration, dispersal and genetic exchange, ecological networks could make a significant contribution to meeting this requirement.

Article 6(3) - Plans or projects that are likely to have a significant effect on a European site can only go ahead if they "will not adversely affect the integrity of the site concerned." This not only directly relates to FCS but is also linked to the specific conservation objectives that are associated with each site. More specifically the integrity of a site has been defined in terms of its "resilience and ability to evolve in ways that are favourable to conservation"; its "inherent potential for meeting site conservation objectives"; and its "capacity for self-repair and self-renewal under dynamic conditions is maintained" (European

Communities, 2000). As with Article 6(1), movement is crucial to maintaining resilience and an ability to adapt to future environmental change.

3 Yorkshire and Humber experience

The methodology, as it was applied in the Yorkshire and Humber Government region, will now be outlined in the following sections. Two different approaches were used to inform land-use planning decisions at both the local and regional scale.

The first section outlines a strategic approach that used a combination of landscape characterisation and UKBAP priority habitat information to set broad environmental objectives. The second outlines a small-scale approach that used a habitat connectivity analysis to define ecological networks for a series of individual priority habitat patches. An annex containing details of a third approach that was applied to river networks and their associated riparian areas for the Regional Spatial Strategy has also been included for the sake of completeness, see annex 2.

The same approach to strategic environmental enhancement mapping has also been explored in the West Midlands, North West and East of England Government regions. The products have since been accepted in the draft Regional Spatial Strategies (RSS) of the North West and Yorkshire and Humber regions and similar products have also been recommended for inclusion in the final draft of the East of England RSS. The remaining Government regions have chosen a variety of different approaches but these were not suitable for wider application as they did not provide an adequate basis for integrating environmental enhancement with wider landscapes or sustainable development.

The smaller scale, habitat network mapping has been applied to both the West Midlands and Yorkshire and Humber regions as a preliminary step to its application across the whole of England. It should be noted that exactly the same method has been applied across both Wales and Scotland and will form the basis for the development of a UK national network. At a regional level, the products will form the basis of some supplementary planning guidance in the Yorkshire and Humber region to help inform Local Development Frameworks and Green Infrastructure planning.

The steps that were necessary to implement these approaches have been summarised in a flowchart contained in annex 3.

3.1 Strategic mapping for RSS

A considerable challenge was presented by the requirement of the Regional Planning Bodies to show information for the complete biodiversity resource in the form of a single, strategic map. After considering the range of different options and the experiences captured from other regions, it was decided that a biogeographic framework, that was based on the National Landscape Typology (Countryside Agency, 2002), would be the best way to express this information. Landscape Character Assessment (LCA) techniques have been widely used in England since the 1970s and provide a method that is used "to classify, describe and understand the evolution and physical and cultural characteristics of a landscape" (Griffiths and others, 2004 p.11). Guidance on the implementation of the general approach can be found in Swanwick and others (2002) and will therefore not be discussed further.

Significant variation in the application of LCA techniques led to an attempt to develop a consistent, national classification through the Living Landscapes Project (Griffiths and others, 2004). One of the key building blocks of this work has been the Landscape Description Unit (LDU) (Warnock, 2002). Although they can be created at different scales, only one classification (Level 1) currently exists for the whole of England with a total of 3069 units and a mean area of 4 340 ha. These are smaller and nested within the Joint Character Framework (JCA). Each Level 1 (LDU1) unit area represents a discrete and homogeneous tract of land, of varying size, that is defined by a particular combination of distinct natural and cultural attributes. They enable landscapes to be identified and provide an ideal framework in which other information can be 'packaged'. Four separate attributes are used to define the framework at this scale: physiography (geology and elevation), ground type (soils), land cover (woodlands and land use) and settlements (pattern). Further details of the classification can be found in annex 4 whilst the spatial arrangement of LDU1s across the region can be seen in figure 4.

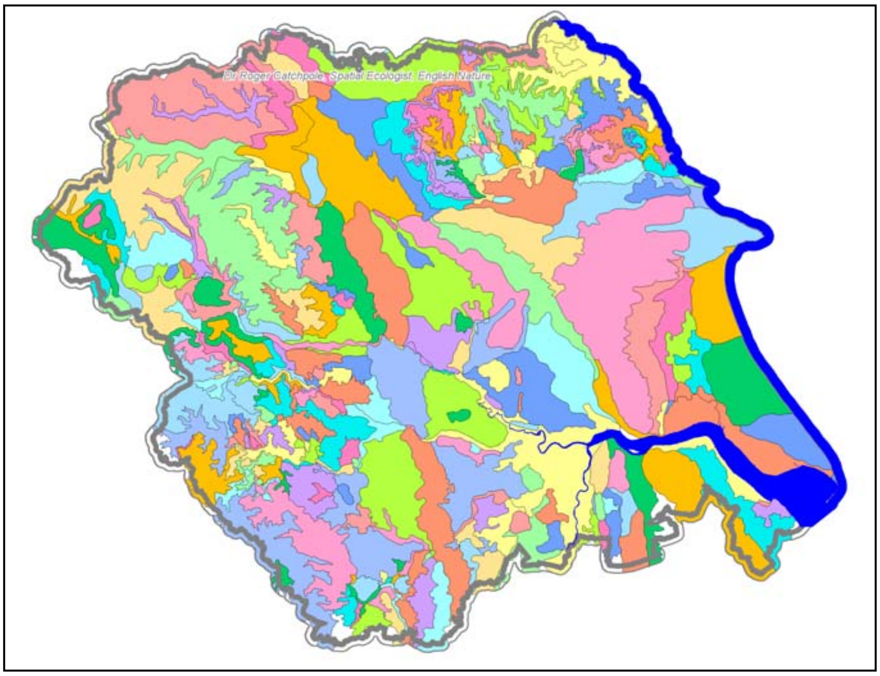

Figure 4: Landscape Description Units (LDU1) across the Yorkshire and Humber Region.

LDU1s that overlapped with the Government Office Region were used to 'package' information on the extent of UKBAP priority habitats. The use of this type of biogeographical classification provides a much stronger basis for the expression of environmental information in contrast to geopolitical classifications that often have little association with natural landscape features. The main benefit that arises from the use of a biogeographic approach lies in its indicative quality. Areas are defined on the basis of physical characteristics that will determine the presence of particular habitats, eg calcareous grassland. When significant remnants are present, it provides a coherent geographical area over which conservation and restoration activities might be considered.

Habitat inventories for 23 terrestrial, UKBAP priority habitats were used as the basis for the following work. This information has been derived from a variety of geographical information sources and was first published by English Nature in April 2004 (Nature on the Map, 2004). Although they provide information for individual priority habitats, data quality issues and the intended end use meant that they were used in an aggregated form for this work. This was also regarded as providing data which were fit for purpose. The inventories were aggregated in the following manner. A **grassland** layer was created by merging inventories for lowland calcareous grasslands, lowland meadows, lowland dry acid grasslands, upland calcareous grasslands and upland hay meadows. A **heathland** layer was created by merging inventories for upland heaths and lowland heaths. A **woodland** layer was created by merging inventories for lowland mixed deciduous woodlands, upland oak woods, upland mixed ash woods, wet woodlands, lowland beech and yew woodlands (not applicable to Yorkshire and Humber Region) and ancient woodlands. A **mire/fen/bog** layer was created by merging inventories for reedbeds, fens, lowland raised bogs, blanket bogs and purple moor grass and rush pastures. The location of mires was also included from statutory site information. No information from the coastal floodplain and grazing marsh inventory was included because of the poor reliability of this data at the time of publication.

After aggregation, each inventory was compared with statutory data and any missing statutory habitat was added. All adjacent polygons that were within 3 meters were merged and any overlaps removed. Statutory data was then used as a ‘cookie cutter’ to remove mis-classified habitat from each inventory, eg a geographical layer containing statutory heathland was used to ‘cookie cut’ (delete) any grassland that overlapped with statutory heathland. Any remaining overlaps were then removed sequentially through using the inventories themselves as the ‘cookie cutters’. They were applied in the following order that was determined by the confidence in the data: woodland, grassland, mire/fen/bog, heathland. All inventories were then disaggregated to prepare them for a geostatistical analysis that would enable the removal of polygon remnants created from the ‘cookie cutting’. The area:perimeter ratio was calculated for each polygon. All polygons below or equal to $50m^2$ were deleted, as were any polygons with an perimeter:area ratio greater than 0.2. This enabled the removal of small polygon fragments that had resulted from the preceding geographical manipulations.

Although this information is still provisional and subject to refinement, it represents the best available information on the extent of these habitats at larger scales at the current time. After this process was completed the information was then used to create a map that showed the regional extent of the aggregated priority habitats within each LDU1. The results for each of the aggregated habitat types are shown in figure 5.

Preliminary work considered the use of a range of geopolitical and biogeographic frameworks but only LDU1s suited local requirements. The effect of scale on the measurement of landscape pattern is considerable and has an extensive literature. The simple measures of habitat density used in this project as well as more complicated landscape metrics are both profoundly influenced by changes in scale (Gergel and Turner, 2002). Scale is usually described in terms of grain and extent. The grain describes the finest level of spatial resolution, eg $10km^2$ and the extent describes the area under consideration, eg England. While extent remained constant, ie regional, the grain of different geographical frameworks varied considerably. The influence of this can be seen in figure 6.

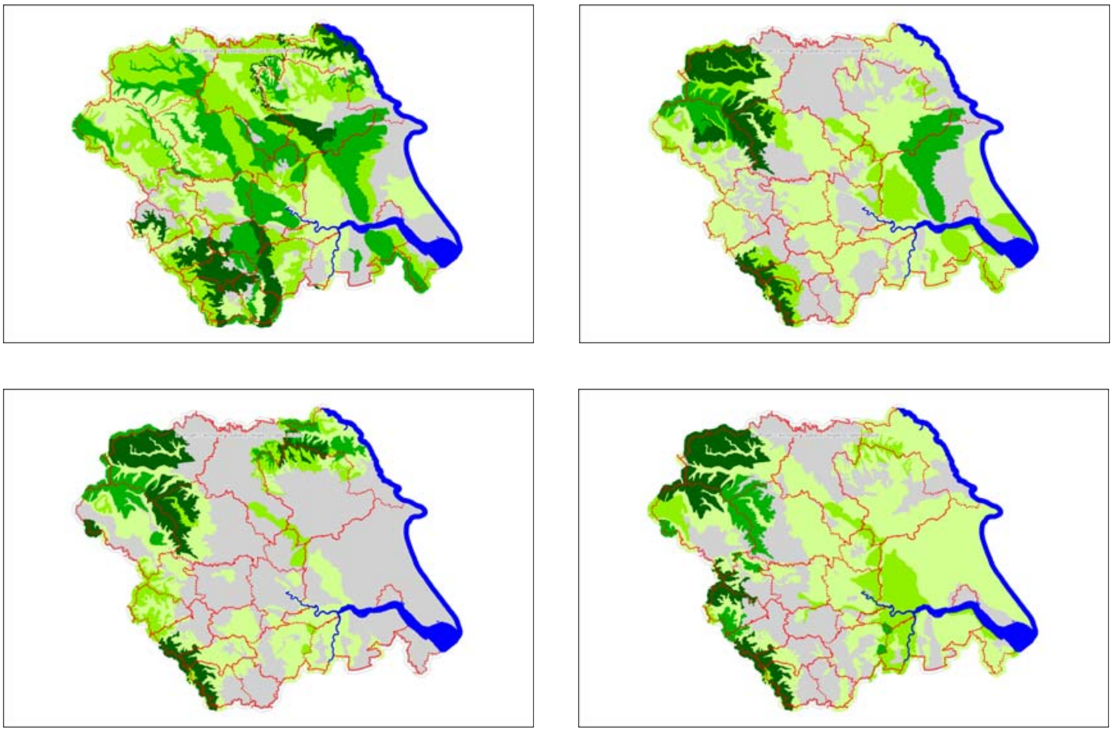

Figure 5: Regional significance of aggregated UKBAP priority habitats within LDUs. Top left = woodlands, top right = grasslands, bottom left = heathlands and bottom right = mires, fens and bogs. Grey stripe indicates no information and red dotted line indicates LPA boundaries.

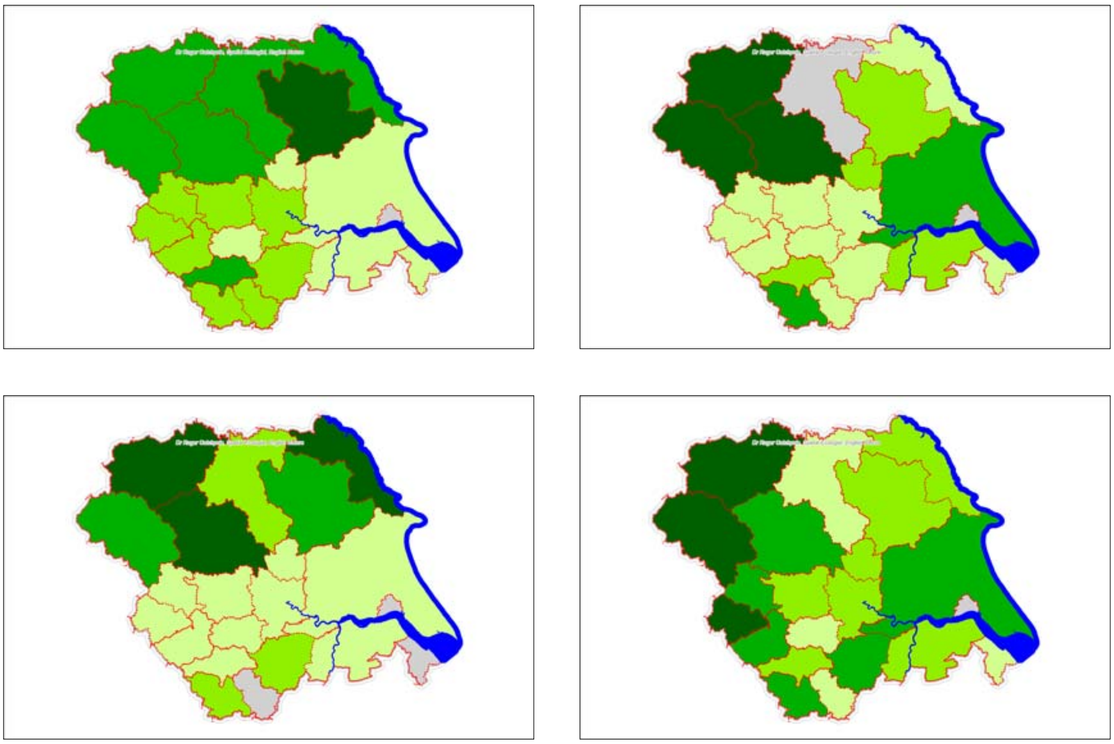

Figure 6: Regional significance of aggregated UKBAP priority habitats within district authorities. Top left = woodlands, top right = grasslands, bottom left = heathlands and bottom right = mires, fens and bogs. Grey stripe indicates.

In practical terms, this type of approach is not suitable for prioritising action because the answer will be strongly influenced by the selected geography. As a general rule the smallest possible geographical framework should be used but other factors, such as differences in survey effort and surveyor bias, can also add further complications. However, the approach is suitable for broad objective setting for environmental enhancements when a single geographical framework is used and the outcome is balanced by local stakeholder knowledge. The maps shown in figure 5 and 6 were produced by calculating the proportion of the total area of habitat in the region that occurred in each geographical area. This was done for each of the four aggregated inventories. The final map, shown in figure 7, was produced by simply summing the proportion of each aggregated inventory within each LDU1.

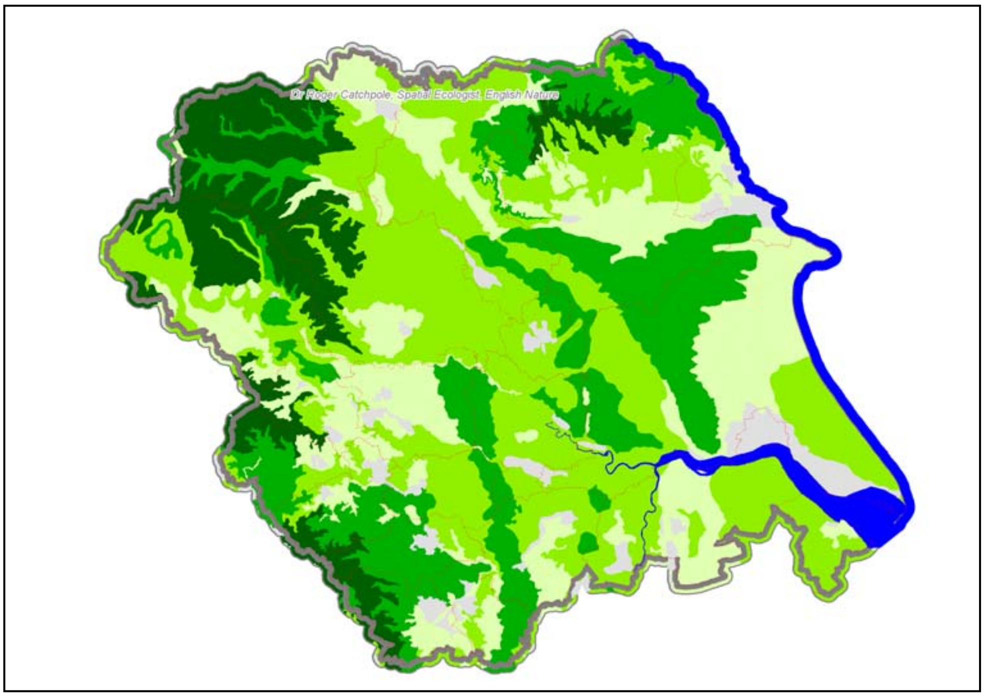

Figure 7: Regional significance of all UKBAP priority habitats. Darker green indicates greater extent of priority habitat. Grey indicates no information and red dotted line indicates LPA boundaries.

Although the analysis could have been scaled to LDUs as a proportion of each unit, this skewed the results and over-emphasised smaller areas to an unacceptable degree. The thematic representation of the analysis relied on a method (natural break) that preserves the underlying pattern of the spatial information (Jenks and Caspall, 1971). Four categories were set so that core areas could be defined in combination with three different types of enhancement area. The boundaries between different landscape description units that fell within the same category were then merged to improve the clarity of the thematic map. At each stage the outputs were validated using the expert judgement of key stakeholders who had a detailed knowledge of natural capital across the region, see annex 5. This approach was based on the thinking of McIntyre and Hobbs (1998) who used the degree of landscape modification to set appropriate goals for conservation. Their approach identifies objectives for the ‘maintenance’, ‘improvement’ and ‘reconstruction’ of biodiversity. These objectives were set depending on the extent of natural habitat destruction that had occurred in geographically distinct areas. This can, however, be further simplified to provide a continuum between conservation and re-creation, as shown in figure 8.

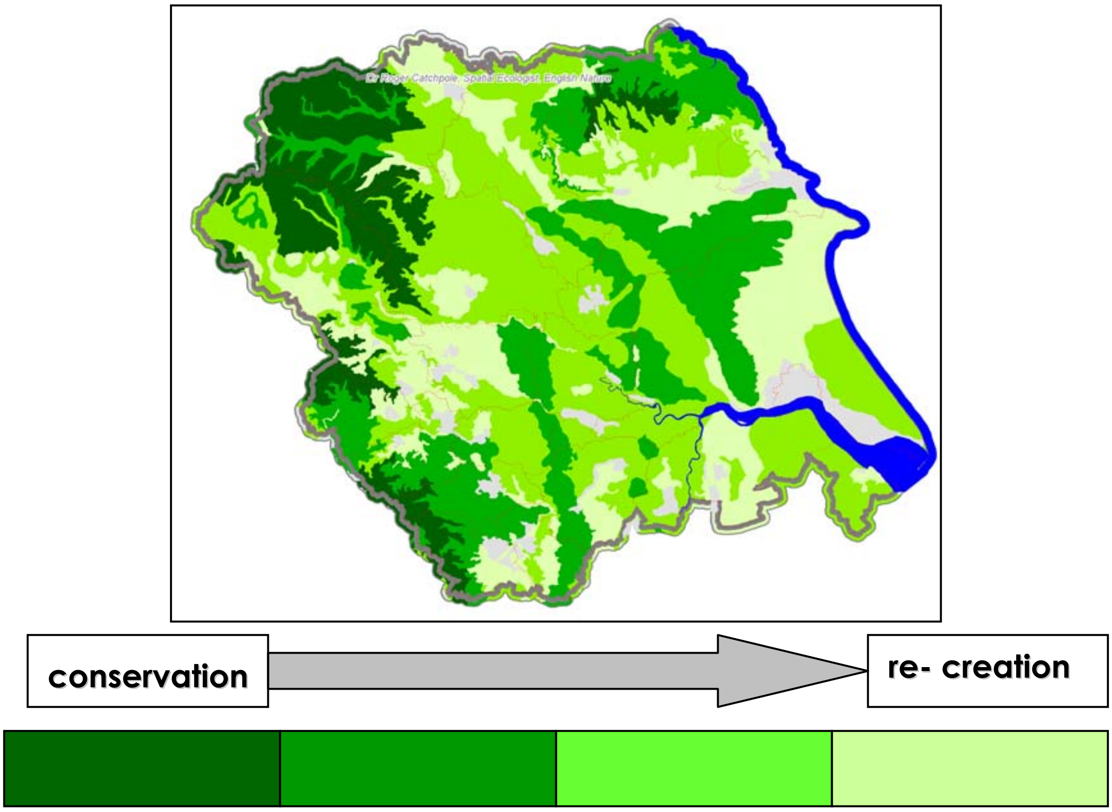

Figure 8: Background to policy objective setting for terrestrial habitats across the Yorkshire and Humber Region. Lighter tone indicates lower density of UKBAP priority habitats. All habitats included. Grey indicates no information.

The thinking of McIntyre and Hobbs (1998) was used, in combination with finer scale spatial analyses of terrestrial and river habitats, to define the objectives that are outlined in table 1 and table 2.

Table 1: Terrestrial and coastal/estuary objectives included in the draft Yorkshire and Humber Regional Spatial Strategy.

		BIODIVERSITY CHARACTERISTICS	POLICY DEVELOPMENT	POLICY IMPLEMENTATION
HABITAT AND RIVER/FLOODPLAIN ENHANCEMENT AREAS	TYPE 1	Within Type 1 areas UK BAP priority habitats dominate the landscape. The Region's core biodiversity resource, often of international significance, is in this zone	Policy should recognise, and seek to maintain and restore the biodiversity resource.	Decisions should ensure the maintenance, and wherever possible restores, the integrity of the biodiversity resource.
	TYPE 2	Within Type 2 areas UK BAP priority habitats are less extensive than above, but to some extent they still form a functioning network across the landscape.	Policy should recognise biodiversity networks and seek to strengthen their integrity by expanding patches of high quality habitat, and enhancing links between them. Opportunities for strategic habitat restoration should be sought.	Decisions should seek to expand and enhance networks and should seek opportunities to strengthen them, by contributing to the strategic restoration of habitats.
	TYPE 3	Within Type 3 areas UK BAP priority habitats restricted to isolated sites, separated by large areas of intensively managed farmland and/or urban areas.	Policy should recognise and protect isolated biodiversity features and encourage their expansion	Decisions should protect isolated biodiversity features and should seek opportunities to expand and buffer them, thereby providing protection from external impacts.
	TYPE 4	Within Type 4 areas UK BAP priority habitats are largely absent.	Policy should encourage recreation and restoration of multi-functional semi-natural habitats.	Decisions should accommodate and allow for restoration of multi-functional semi-natural habitats.
	COASTAL/ESTUARY	The Region's coastline and estuaries are of international importance for species and habitats.	Policy should recognise and enable natural processes to be sustained and the resulting changes to the coastline managed.	Decisions should ensure the maintenance the natural processes are sustained to maintain the integrity of the biodiversity resource.

Table 2: Riverine objectives included in the draft Yorkshire and Humber Regional Spatial Strategy.

		BIODIVERSITY CHARACTERISTICS	POLICY DEVELOPMENT	POLICY IMPLEMENTATION
HABITAT AND RIVER/FLOODPLAIN ENHANCEMENT AREAS	CATEGORY 1	Category 1 represents the Region's core river and floodplain resource where existing features support UK Species of Conservation Priority. Category 1 includes statutory designated sites.	Policy should recognise and seek to maintain and restore the biodiversity resource.	Decisions should ensure the maintenance, and wherever possible, restore the functionality of the biodiversity resource.
	CATEGORY 2	Category 2 represents areas of varied biodiversity quality, where there is a need to improve physical and biological continuity for migratory BAP species.	Policy should recognise river networks and seek to enhance the physical and biological continuity of such ecosystems. Opportunities for strategic habitat restoration should be sought.	Decisions should seek to maintain and restore functional floodplain habitats and associated flooding regimes and avoid obstruction of river continuity.
	CATEGORY 3	Category 3 represents poor riverine habitats in areas of strategic importance for the restoration of the river network and associated biodiversity. It includes some areas of high biodiversity quality	Policy should encourage recreation and restoration of multi-functional semi-natural habitats.	Decisions should accommodate and allow for restoration of multi-functional semi-natural habitats.

After adding a range of other information, the final opportunity map was produced which can be seen in figure 9. This information included important coastal and estuarine areas as well as riverine enhancement areas. The former was defined by the location of statutory sites which were buffered by 1km to allow for the management of dynamic coastal processes. The way in which the latter was defined has been outlined in annex 2 and will not be discussed further at this point.

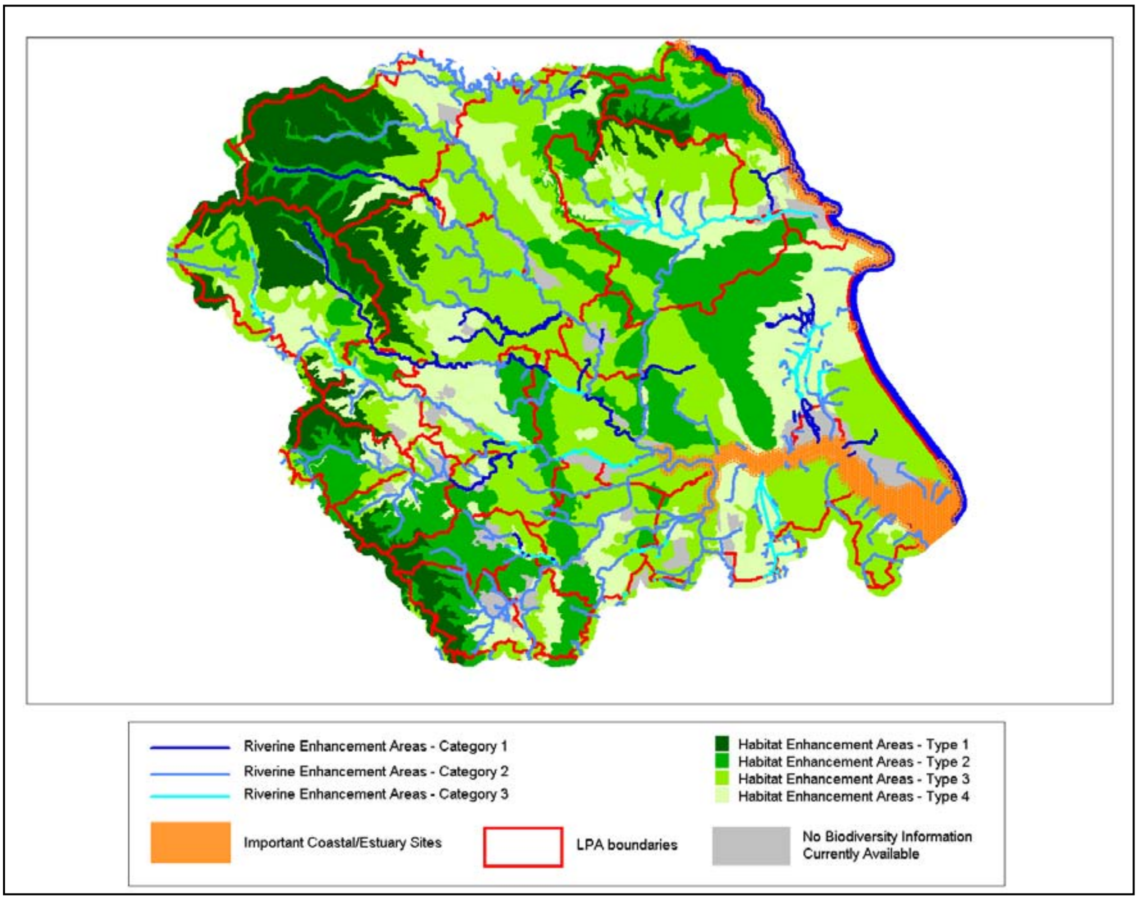

Figure 9: Combined map included in the draft Yorkshire and Humber Regional Spatial Strategy.

Policies associated with strategies for each area were developed to complement the map-based outputs. An initial draft was provided by the author and then adapted by the Regional Biodiversity Forum. Close liaison between the Forum and the Yorkshire Assembly was facilitated by the placement of an English Nature Regional Biodiversity Officer within the Assembly. After some minor presentational changes, both the map and associated policies were included in the draft by the designated officer.

3.2 Habitat network methodology

Indicative habitat networks were created by an analysis that considered the **potential** extent of 'functional connectivity' between existing terrestrial habitats in the region. Exactly the same inventory-based habitat information, which has been described in the previous section, was used in this analysis. This was done by the application of 'least-cost' methods that are outlined in annex 1 and associated publications (Catchpole, 2005). The products arising from this analysis were produced to provide 'signposts' as to where the **maintenance and enhancement** of current clusters of habitat might be delivered on the ground. Whilst the preceding analysis is only intended for setting broad objectives for strategic environmental enhancement, the network analysis is intended to support operational delivery at finer scales. The use of biogeographic frameworks is not suitable for defining where specific environmental gains might be secured at the level of the individual land parcel. It should be noted that both approaches are necessary to adequately deliver PPS9 obligations. As the network definition is based on the current arrangement of patches and the intervening land cover, it only indicates opportunities for the maintenance and enhancement of the **existing** resource and **not** wider habitat restoration potential. Other work has focused on developing a stakeholder-led, habitat potential toolkit for this purpose (Catchpole, 2006).

The 'least-cost' method requires two basic, spatially referenced inputs: a habitat layer and a land cover layer. The habitat layer contains the spatial arrangement of the habitat patches that are of interest, while the land cover layer provides an estimate of the hostility of the matrix in-between those patches. For the purpose of the current analysis, the habitat layers were derived from a combination of the aggregated national inventory data while the land cover layer was derived from satellite-based remote sensing data, Land Cover Map 2000 (LCM2000, ITE). The results are determined by the definition of the relative movement costs across different land cover elements. This involves weighting different land cover types with an assumed 'movement cost' that then determines the extent of the networks. This could be calculated empirically but in practice expert judgement is most commonly used (Vebeylen and others, 2003). An example of how different land cover elements might be weighted is given in table 3.

Table 3: Example of cost allocation for a woodland network adapted from Watts and others (2005)

Ecological Cost	Land Cover Type	Movement Costs (as a function of distance for a 1km network)
LOW	eg broadleaved deciduous woodland	**1 – high permeability** dispersal distance = 1000 ecological cost = 1 movement 1000/1=1000m
	eg broadleaved scrub	**3 - medium high permeability** dispersal distance = 1000 ecological cost = 3 movement 1000/3= 333m
MEDIUM	eg bracken	**10 - medium permeability** dispersal distance = 1000 ecological cost = 10 movement 1000/10= 100m
HIGH	eg rough neutral grassland	**20 - medium low permeability** dispersal distance = 1000 ecological cost = 20 movement 1000/20= 50m
	eg arable - cereals	**50 – low permeability** dispersal distance = 1000 ecological cost = 50 movement 1000/50= 20m

Although the model can be run to suit individual species requirements, its value lies in more general application, as the 'movement cost' across different types of land cover will never be known for most species of conservation interest, Watts and others (2005) have proposed what they call a 'generic focal species' approach to define these costs. This draws on spatially explicit approaches that have been developed for focal species and ecological networks (Lambeck, 1997; van Rooij and others, 2003). The approach assumes that species can be grouped by habitat preference, dispersal ability and minimum area requirements. In spite of the fact that attempts to define minimum areas have a long history (eg Pickett and Thompson, 1978), the area requirements of most species of conservation interest are likely to remain unknown. While there is considerable benefit and some support for making general assumptions about the other factors (eg Brooker, 2002; Opdam and others, 2003), any attempt to define minimum areas lacks an empirical basis and could also incur unnecessary cost. This is because conservative estimates (eg Saunders, 2005) could lead to the management of unnecessarily large areas. As a consequence, the current approach has made no such assumptions. It simply developed generic costs for movement of broad species assemblages across different land cover types. This was calculated at three maximum dispersal distances, for species associated with woodlands, heathlands, grasslands and mires/fens/bogs.

The general 'movement costs', across different land cover elements, were determined by expert judgement. This was done in consultation with English Nature specialists who were asked to provide an estimate the relative movement costs of species associated with the broad habitat types that were considered, see annex 6 for details. Clearly this approach ignored the significant heterogeneity that is generally observed in relation to species assemblages that might occur at a given location as well as their associated dispersal behaviour. Although this was not entirely satisfactory, the lack of empirical information, availability of alternatives and limitations of the habitat inventory data necessarily defined the approach that was used. In other words, it can be viewed as being fit for purpose. Further testing, using alternative models and population genetic analyses, is planned to support this work and frame future refinements. The capture of a wider range of dispersal profiles is also planned.

Once defined, the 'movement cost' estimates (as defined through expert judgement) were attached to the land cover layer and 'least-cost' distances were calculated. This was done through use of the Spatial Analyst extension to ArcGis 9 (ESRI, 2004). The method calculates the path along which the lowest 'movement cost' is present between a series of focal patches. The analysis produces a 'movement cost surface' that **indicates** the functional connectivity that might be present between existing patches of habitat. An example of some of the more detailed output can be seen in figure 10.

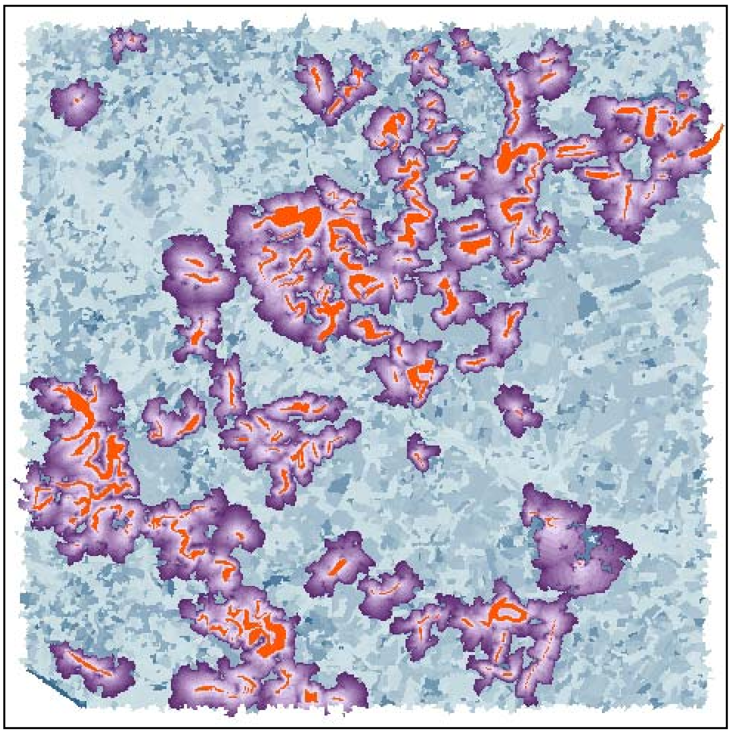

Figure 10: Example of habitat connectivity indicated by least-cost analysis of calcareous grassland in Dorset. Orange=grassland patches, blues=LCM2000 land cover types, dark mauve=area of high cost to movement, light mauve=area of lower cost to movement.

An analysis was not only undertaken for four different habitats, at three different scales, but also for three different types of site. Networks were defined for the complete resource (inventory); a sub-set consisting of statutory sites (SSSI) and further sub-set just consisting of Special Areas of Conservation (N2K). This was done to provide flexible outputs that could be used for different habitats, at different scales and with different types of site. This flexibility was further enhanced by defining the extent of overlap between the main network types and classifying networks as ‘mixed’ if more than 10% of their area overlapped with another network. The layers were structured in such a way that users can select different thresholds if required. This was done so that action can be targeted either in specific biotopes or in areas of greater heterogeneity. A total of 36 different options were generated from the analysis. A summary of the outputs that were produced can be seen in table 4.

Table 4: Analytical structure and GIS outputs for the habitat network analysis across the Yorkshire and Humber Region. N2K=Natura2000 SAC sites.

habitat type	patch type	maximum dispersal distance		
		500m	1km	2km
woodlands	N2K			
	SSSI			
	inventory			
grasslands	N2K			
	SSSI			
	inventory			
heathlands	N2K			
	SSSI			
	inventory			
mires & fens	N2K			
	SSSI			
	inventory			

Each coloured cell in the table represents a different GIS information layer. Users have a total of 36 different choices depending on the type of habitat, eg woodland, type of site, eg statutory and maximum dispersal distance, eg 2km. This was done to try to provide flexible outputs that would suit a range of needs. The different layers were arranged in a standard format within MapInfo Professional and distributed to users so that the information could be easily accessed, see figure 11.

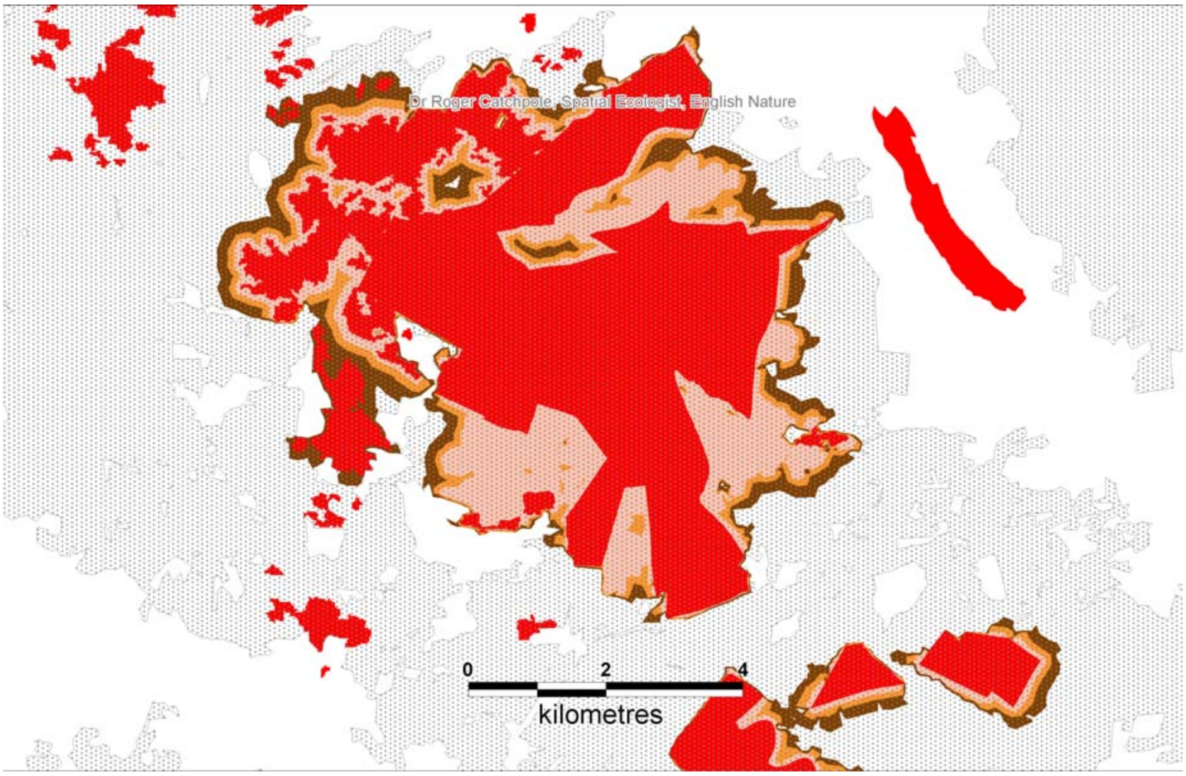

Figure 11: Standard MapInfo workspace. Red=N2K mire/fen/bog sites, pink=500m dispersal interval, orange=1km dispersal interval, brown=2km dispersal interval, grey stipple=areas with more than one network.

The main patch in figure 11 has a series of halos shown in three different colours that indicate the network extent for the three different dispersal intervals that were set. Other patches show no halos because they occur in a potentially more hostile land use context, ie areas where the land cover differs significantly from the patch type and is assumed to be less permeable to movement. In such circumstances the network will not extend beyond the patch boundary. The dispersal intervals that were selected were arbitrary and only intended to provide outputs that would be relevant to species with moderate dispersal abilities. They do not apply to highly sedentary species, eg some deadwood saproxylics or highly vagile ones, eg most birds. They simply provide some 'bookends' within which a range of species might be considered. The intention has been to encourage local decision-makers to 'retro-fit' groups of species to the most suitable dispersal intervals. For example, a local biodiversity action plan group might want to consider how to target action for a woodland species, with a limited dispersal ability, across a network of non-statutory habitats. In contrast, a statutory agency might only be interested in delivering Article10 (Regulation 37) obligations for a species, with medium dispersal ability, across a network of Natura2000 habitats. Once the network type and dispersal interval has been selected, the wider 'functional footprint' of individual patches can be defined. An example of this is shown for the 2km maximum in figures 12 and 13.

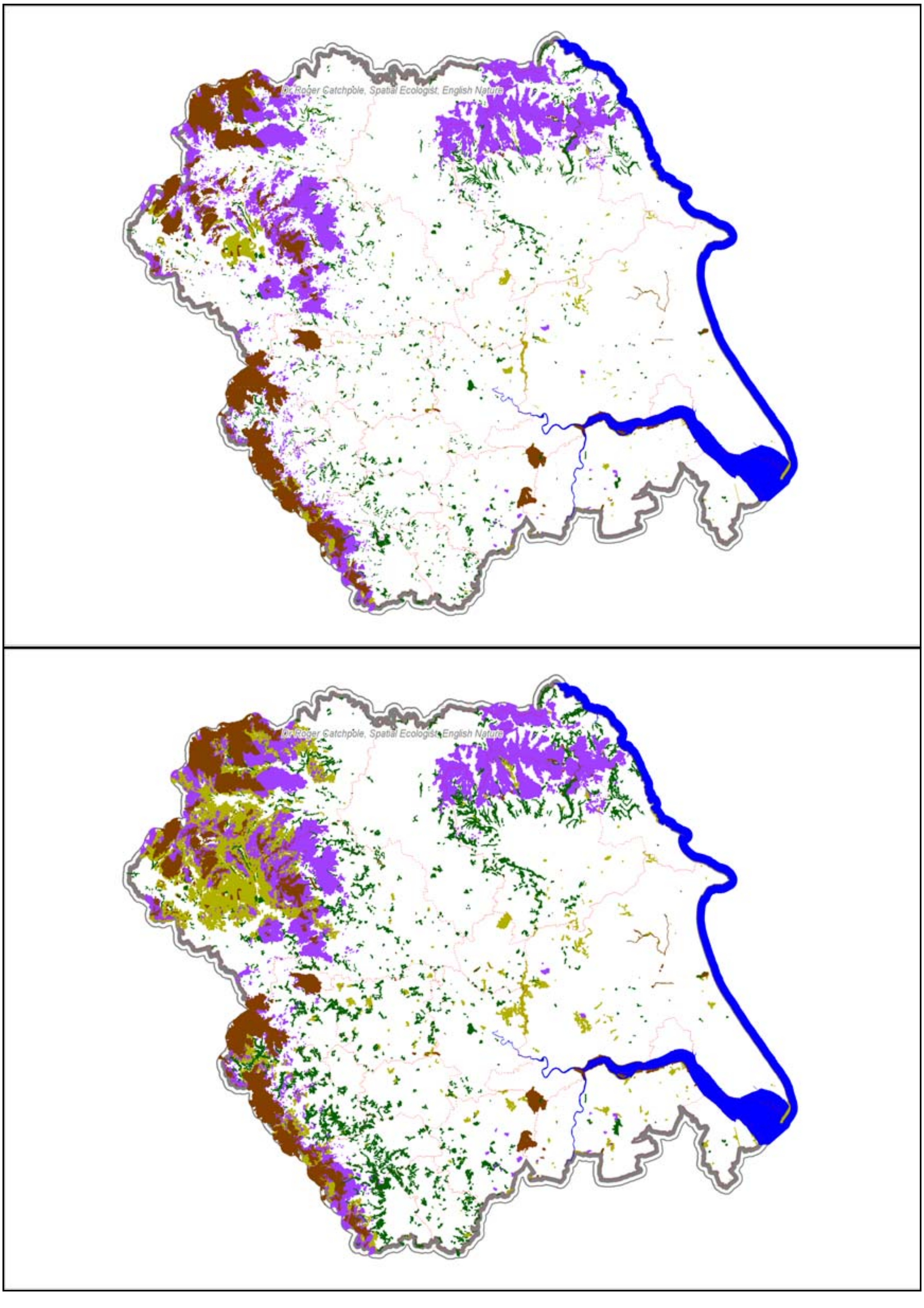

Figure 12: Indicative networks of UKBAP priority habitats across the Yorkshire and Humber Region as defined by a 2km dispersal maxima. Top map shows inventory boundaries and the bottom map shows network boundaries. Habitat types are shown in different colours: brown=mire/fen/bog, purple=heathland, kaki=grassland, dark green=woodland.

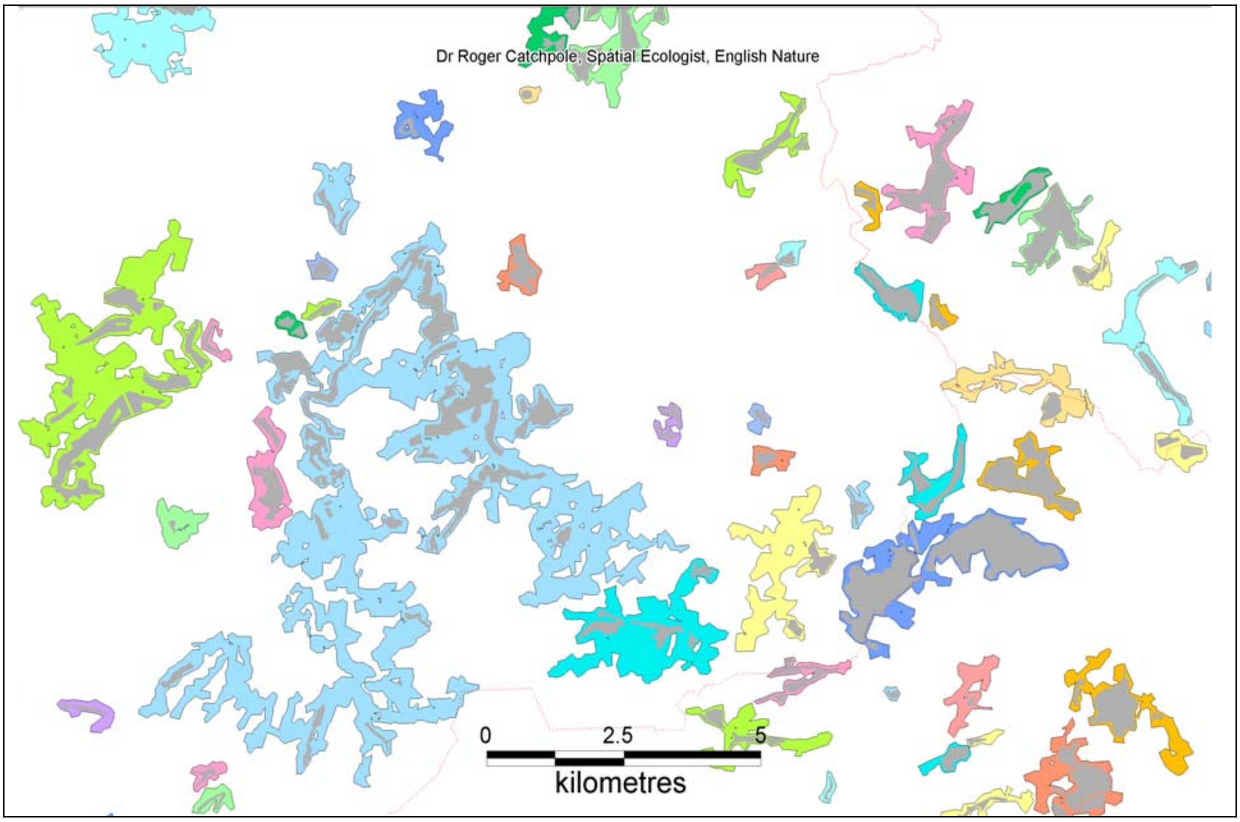

Figure 13: Indicative woodland habitat networks at a finer scale. Current woodland patches are shown in grey. Different colours indicate different indicative habitat networks for woodland species with a maximum dispersal distance of 2km. The extent of each network is determined by the maximum distance and generic movement costs that are used in the analysis. They indicate the areas of landscape between patches that might be more permeable to woodland species by assuming movement will more readily occur across land cover of a similar type. As it is a generalisation some species will always move beyond the defined boundaries.

It should be noted that the distances represent **maxima** over which it might be possible for, say, a woodland species to travel if the land cover beyond the patch is similar to woodland. Where it is not similar, then the likely distance that a species might move would be considerably shorter depending on the hostility of the intervening land use. Further refinements are planned to scale these distances to different habitats and understand which species of conservation interest would benefit from being managed in this way.

In summary, the method indicates not only which patches may be part of a wider functional network, as can be seen from figure 13, but also where habitat restoration and land use extensification **might** be most effective. It offers opportunities for the enhancement of the ecological integrity of existing habitat within the context of current land use rather than more 'visionary' habitat restoration schemes that are often less likely to be realised in practice. It works with the grain of the current landscape and offers a coherent approach to climate change adaptation. An example of how this might be used in practice is given in the following section.

4 Networks in practice

The following example was created to show how the outputs from the different analyses might be used in practice by local stakeholders (Catchpole, 2005). The location of the demonstration area is shown in figure 14.

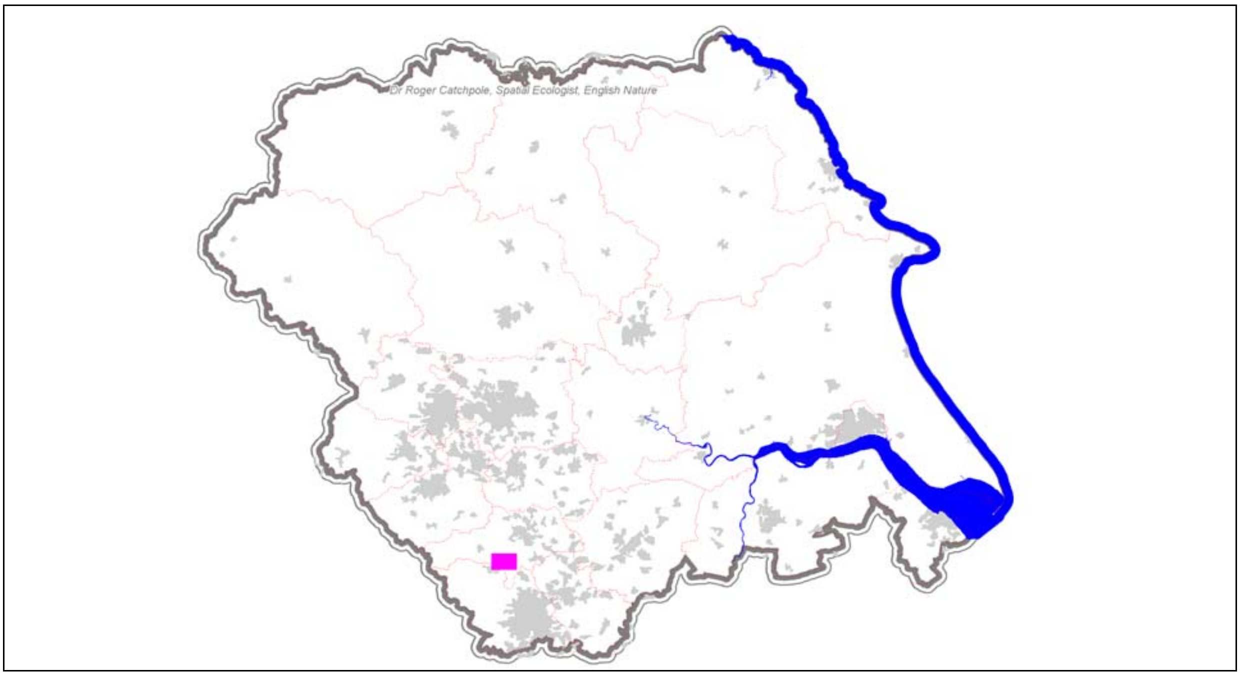

Figure 14: Proposed case study area.

One possible way in which the information that has been generated might be used is through a two-dimensional version of the *Planning for Real* © participation method that was first developed by the Neighbourhood Initiatives Foundation (Gibson, 1998). Although part of the 'local model' has already been defined, the approach will provide stakeholders with a common point of departure for dealing with complex ecological issues. Such an approach would not only empower local decision-making but also ensure that an informed judgment can be made in the absence of ecological specialists. Given the significant inequalities of knowledge that are clearly present between different localities, this becomes an important issue. This would not only empower local communities to make judgements but also help to ensure a more consistent response to strategic issues such as habitat fragmentation and climate change.

The area that was chosen has a significant woodland resource which meant that only one type of network was considered. It was also selected to include a section of river so that both terrestrial and freshwater issues could be included. Clearly there would be smaller-scale opportunities for the creation and management of other complementary/transitional habitats, but the main focus for any stakeholder group in this area would be a broadleaved woodland network. In other parts of the region the emphasis shifted depending on the extent of different habitats represented in the inventories that were used in the analysis. Only the results for species with a 'high' (ie 2km maximum distance) dispersal capacity have been shown for the sake of brevity in this example, see figure 15.

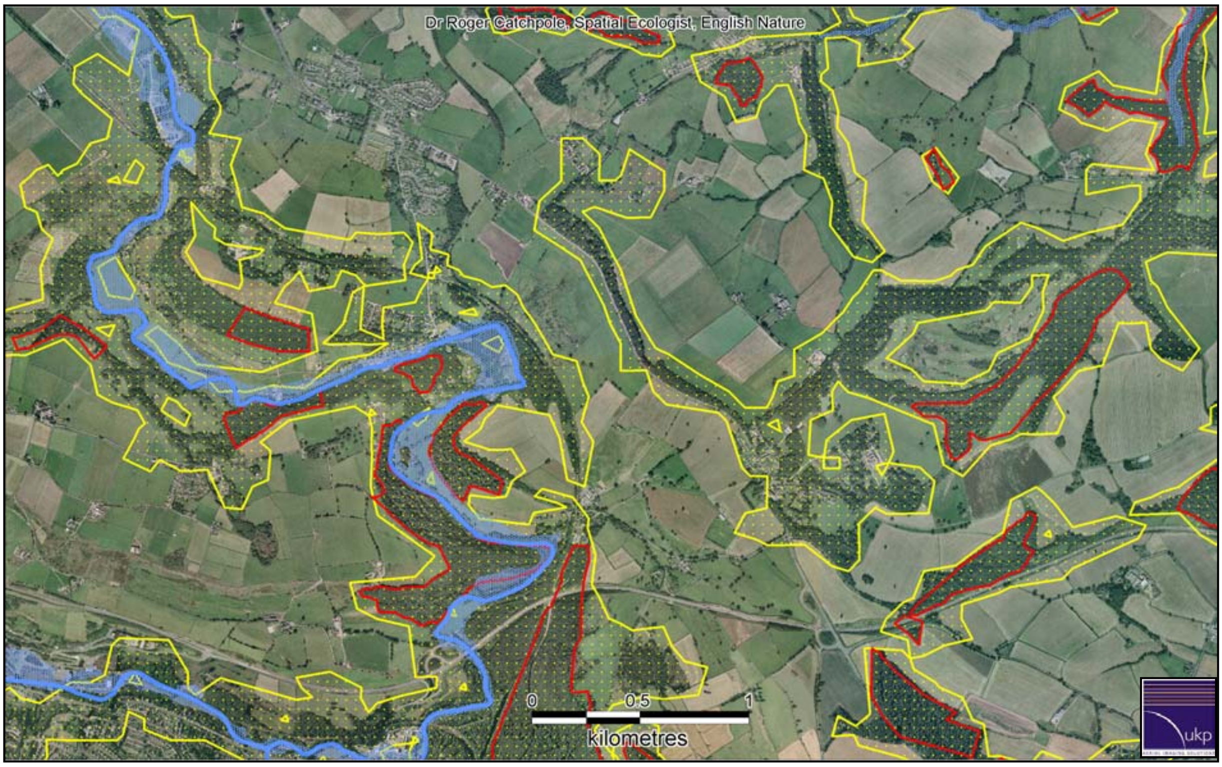

Figure 15: Case study area showing 2km woodland networks (yellow), woodland inventory sites (red) and a Category 2 river with an associated flood zone (blue stipple).

In reality, three different distances might be considered in order to select the most appropriate framework for the range of focal species that might be present in any given area. The use of aerial photography was particularly useful as it provided a partial validation of the results. The areas of potentially lower movement cost showed a good correspondence to areas of woodland that were not included in the original inventory as well as areas of scrub that **might** be considered to be generally more permeable to the movement of woodland species. It is envisaged that this type of map would be used as a common starting point for engagement with local stakeholders. Even in the absence of local knowledge, it was still possible to arrive at some conclusions as to where best locations might be for the management and restoration of different habitats. When used in this way, the approach can act as a coarse geographical filter which then enables users to consider the potential for habitat maintenance and enhancement in a more focused manner. Although significant refinement of the initial outputs would be possible through this process, further ground-truthing would clearly need be undertaken prior to any project implementation. The results of such an exercise might resemble the 'mock' vision map that is shown in figure 16.

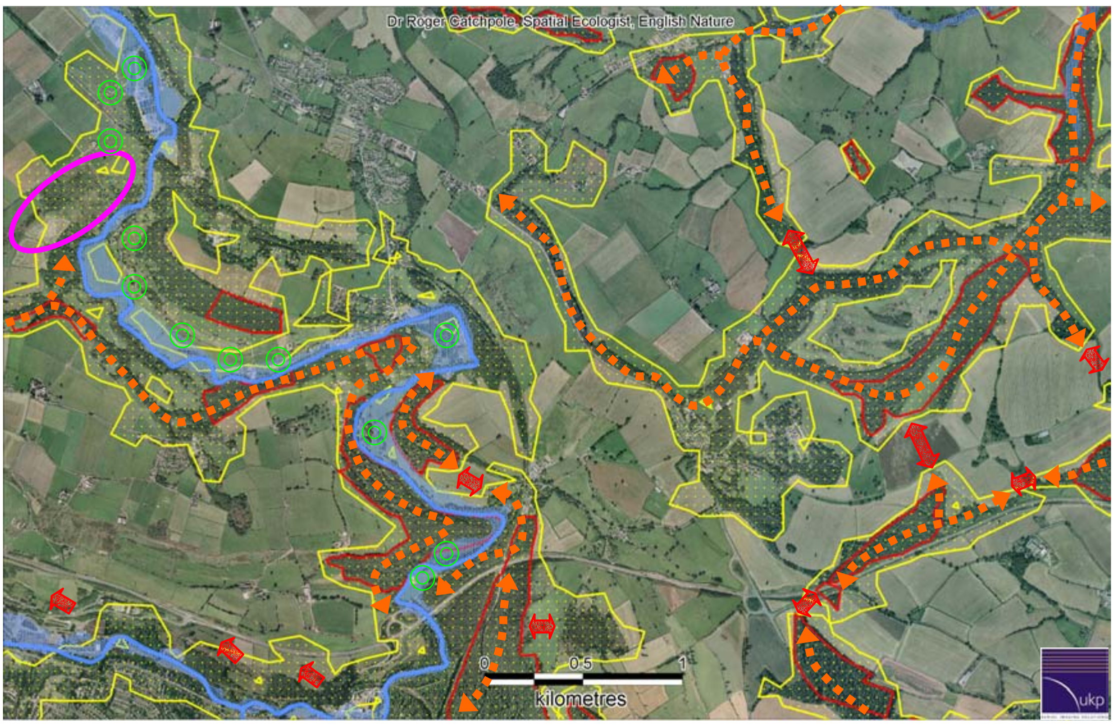

Figure 16: Example of local habitat opportunity map that could be developed from a connectivity analysis. Blue areas indicate flood zones subject to periodic inundation. Magenta oval indicates existing heathland restoration zone. Green rings indicate areas to be managed as transitional biotopes. Red outline indicates boundaries of woodland inventory areas. Yellow stipple indicates the total area through which a species **might** be able to disperse from the woodland inventory patches (assuming a 2km dispersal maxima). Orange dotted line indicates the main axes of the network. Red arrows indicate potential areas for woodland expansion at key pinch points.

Information on the distribution of Red Data Book species and County Wildlife Sites was used to determine whether any additional wildlife interest was present in the study area. It should be noted that no account was taken of built infrastructure, such as roads and buildings, which meant that the habitat network extended across such features in some areas. The extent to which such features are barriers to movement varies. If assumptions are made about potential impacts on local biodiversity then this would have limited the flexibility of the resulting outputs. In practice, such determinations should be made by local stakeholders. This example illustrates how it might be possible to enhance the ecological integrity of sites through small-scale actions at key locations. It could help to maintain and strengthen previous conservation investments and provide realistic opportunities for action that are consistent with current land management policy and practice. This contrasts significantly with approaches that only advocate large-scale conservation delivery where large areas are specifically co-opted for conservation (eg Saunders, 2005).

5 Conclusions

The approaches that have been developed meet conservation needs at both a strategic and local level. The work demonstrates how strategic, character-based frameworks can be used in conjunction with biodiversity information to set realistic environmental objectives across several regions. Evidence of the potential for practical application has already been gained through the adoption of the character-based, strategic framework across three regions that cover approximately 38% of the total land area of England. As a fourth region is likely to follow, this will increase coverage to approximately 47%. The habitat networks will also form the basis for some planning guidance in one region.

At the local level, it also demonstrates how individual sites can be characterised as 'members' of wider network of sites. Both approaches support local participation while ensuring that consistent methodologies are applied over wider areas. For example, the way in which the local networks have been defined, enables users to 'retro-fit' species of local conservation interest while incorporating consistent ecological principles.

Although further testing of the network methodology will be necessary, taken together, the two different approaches clearly provide a direct and pragmatic contribution to setting ecologically robust frameworks for the delivery of Regional Spatial Strategies, Local Development Frameworks, Local Biodiversity Action targeting, Green Infrastructure planning, climate change adaptation and in time, agri-environment targeting.

The work has clearly demonstrated how a common starting point can be defined for local action as well as how consistent responses to strategic issues such as climate change and environmental 'goods and services', might be delivered.

6 Recommendations and issues

1. Climate change is high priority issue across economic, social and environmental sectors. An ecological network approach to planning uses best available evidence to increase the resilience of both countryside and urban areas in adapting to change.

2. Any partnerships that seek to produce biodiversity enhancement maps must base such work on sound, ecological principles and utilise currently available information. Information will always be incomplete but this should not prevent spatial analyses provided the limitations of particular data are understood and boundaries set.

3. Biodiversity enhancement maps must be clear to partners and stakeholders, amenable to testing and contain as few assumptions as possible. Where assumptions have been made these must be supported by an appropriate evidence base.

4. Biodiversity enhancement mapping should be done at different scales that are fit for purpose. The use of contiguous, character-based geographies are most suitable for the broad objective setting, across wide areas, that is typified by the RSS process. This approach avoids polarisation and the definition of areas with no environmental objectives. The use of ecologically realistic, patch-based analyses are most suitable where specific gains need to be delivered on the ground. This is typified by the needs of Local Development Frameworks, LBAPs, Green Infrastructure Planning and agri-environment targeting.

5. Local partnerships need to develop a greater awareness of strategic environmental issues, such as climate change and eutrophication, and any national or regional projects that might be seeking to develop solutions to such problems.

6. Natural England should prioritise the creation of a three tier, character-based common geography, which includes coastal areas, in order to support strategic objective setting at national, regional and local level. At the present time there is a consistent

methodology at the national level (Joint Character Areas etc) but no consistency at the local level. Whilst the methodology for LDU1s is consistent there are few associated applications or uses of this geography in landscape character assessment. Its use, as a more general biogeographic framework, has been more marked.

7 Further testing to establish the reality of any ecological network definition, through standard population genetic techniques, is a priority. As they remain untested, they should not be viewed as fixed 'blueprints' but rather as a signpost for local stakeholders.

8 The circumstances under which ecological networks should be used as a conservation tool must be more clearly understood. In particular when it has the potential to complement existing, site based conservation activity and which species of conservation interest might benefit.

9 Local partnerships must be aware of the need to apply a consistent methodology to the definition of ecological networks and should take account of any national and regional network development.

10 The extent to which ecological networks can provide a more coherent basis for the environmental (as opposed to social) aspects of green infrastructure planning and local development frameworks should be examined and further developed.

11 Any definition of a national network must be based on a direct evaluation of the functional connectivity of terrestrial and riverine systems. It should not be assumed that rivers provide an ecological network by default, nor that any existing initiatives will evaluate the physical and biological continuity of river systems in a systematic manner.

12 The use of what has been defined as the 'countryside character approach' is not appropriate for the definition and management of ecological networks in England and the UK position should be more clearly communicated at a European level.

13 Although they meet the needs of local stakeholders, the widespread implementation of the two different approaches, that have been described in this report, is still lacking. Evidence needs to be gathered to document how each approach stimulates proactive delivery and how they will influence the work of Natural England in meeting its objectives.

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Annex 1: The importance of movement

Movement is critical at a number of different organisational levels. At the level of the gene, movement is critical to avoid the effects of non-random mating in populations of outcrossing individuals, ie those species that do not reproduce though self-fertilisation or parthenogenesis (Hedrick, 1985). When a limited number of individuals are present, as is often the case in small patches of isolated semi-natural habitat, the degree of relatedness between individuals that reproduce will be greater than chance. This causes inbreeding which often leads to the expression of deleterious recessive genes and a loss of genetic variation, both of which will significantly reduce the fitness of the population and increase the risk of local extinction. Such variation is critical to the ability of a population to adapt to environmental change.

At the level of the population, movement is critical to the persistence of a species at a given location. Within heavily modified landscapes, populations are often sub-divided and exist as metapopulations (Levins, 1970). While some authors have questioned the widespread existence of spatially sub-divided populations (eg Harrison, 1994), more recent work has shown that "innumerable species" exist as metapopulations (Hanski and Gaggiotti, 2004 p.3). Even when not previously present, many species may now find themselves in this situation because of the loss and fragmentation of their habitat. Under this regime, species persist through an ongoing process of local extinction and re-colonisation across a network of patches. **Even though the area of individual patches may be small, the functional area of available habitat can be much greater. When movement between patches is possible species can persist across a wider landscape even when no large habitat patches may be present.**

Another important benefit to movement can also be found in the opportunities that this provides for adaptation to environmental change. For example, at very large scales, significant changes in the bioclimatic envelope of many habitats (Harrison and others, 2001) and species (Pearson and others, 2002) has been predicted. The impact of climate change on small, isolated sites is likely to be high unless spatially consistent adaptation strategies, across wide areas, are adopted. Although a high degree of uncertainty will continue to remain in relation to specific impacts, precautionary approaches that enable species re-assortment clearly need to be developed. For example, simply providing access to a greater range of topographic variation over a limited geographic distance may be sufficient to maintain viable populations at many locations. Changes in thermal regime that result from access to different slope aspects could hold significant benefits for a wide range of plant and animal species. Variation in vegetation structure and composition may also have similar benefits, especially from an invertebrate perspective.

If the need for species movement between patches of semi-natural habitat is accepted as a land use management priority, then the connectivity of the existing resource needs to be evaluated before any areas for enhancement are identified. The connectivity of a landscape has been defined as "the functional relationship among habitat patches, owing to the spatial contagion of the habitat and the movement responses of organisms to landscape structure" (With and others, 1997 p.151). The degree of connectivity is thus determined by more than just the spatial arrangement of patches. It is the behavioural responses of individual species to landscape structure that defines what has been called "functional connectivity" (With, 2002 p.211). This can be thought of as the sum total of the responses that determine how far a species might be able to move in a given landscape. **Approaches that just evaluate**

structural connectivity do not take any account of such interactions and often lack a considerable amount of ecological realism.

The measurement of landscape structure is based on the assumption that there is an interaction between spatial pattern and ecological process (Turner and others, 2001). While there is evidence that a number of structural measurements provide good indicators of population viability (eg Andren, 1992; Verboom and others, 1991; Fagan and others, 1999), establishing a relationship between physical features and connectivity has proved more difficult. For example, using fixed-distance buffers around habitat patches to define connectivity ignores the asymmetrical influence of land use in the patch matrix. This is not adequate because buffering assumes that: 1) species have an equal chance of moving in all directions; 2) the matrix in between the patches has a uniform movement cost; 3) dispersal distances are the same across all landscapes (when published estimates are used); 4) all species have the same dispersal distance.

Functional connectivity can be measured in a number of different ways. The methods that offer the most potential for practical application include landscape cohesion (Opdam and others, 2003), metapopulation capacity (Hanski and Ovaskainen, 2003) and least-cost path analysis (Bunn and others, 2000). Access to tools that would enable the implementation of the first two methods is currently restricted because of mixture of intellectual copyright issues and commercial interests. The third method is not subject to any such restrictions, however, as it relies on a standard option in ArcGis 9 (ESRI, 2004). Although further validation is needed, the approach offers a practical solution that has been applied to a number of species including Iberian lynx (Ferreras, 2001), speckled wood butterfly (Chardon and others, 2003), red squirrel (Verbeylen and others, 2003) and elephants (Osbourne and Parker, 2003). It has also been applied to the creation of generic woodland networks in Wales (Watts and others, 2005). Its application is further explored in section 3.2.

Annex 2: River network methodology

The methodology for the classification of the river networks was derived from the Yorkshire and Humber Wetland Restoration Feasibility Study (Penny, 2005) and recommendations from the wetland sub-group of the Yorkshire and Humber Regional Biodiversity Forum. Some of the following text that has been included has been taken from Penny (2005) and readers are encouraged to look at the original as some adaptation has been necessary in order to make it consistent with previous sections of the current document.

The river network methodology utilised a range of different spatial data, held by various organisations, to identify areas that may be suitable for the restoration of wetland habitat. Although the approach differed, it complemented the results of the terrestrial habitat analyses which did not, in the main, deal with the restoration potential of floodplain areas. The method was based on the approach used in other feasibility studies that had been undertaken elsewhere in England.

Category one rivers and floodplains (ie areas that currently support the greatest biodiversity resource) were selected through the use of County Wildlife Site, SSSI and UKBAP Priority Species information. Stretches were included in this category when they overlapped either with designated riverine sites or significant aggregations of priority species records. When only species records were used, reaches were selected when there was overlap with clusters of records for two or more species.

Category two rivers and floodplains (ie areas that support migratory salmonid and lamprey movement) were selected through the use of Environment Agency fishery survey data. This information was used as an indicator of river stretches where the maintenance of physical continuity is particularly important.

The process that was used to define category three rivers/floodplains (ie the areas that currently have the greatest restoration potential) was necessarily more detailed and consisted of four stages:

Stage 1 involved the broad topographical examination of the study area in order to highlight suitable areas. The following data sets were used:

- Topographic data – indicated flat areas most likely to absorb water.
- Soils and superficial drift geology data – indicated potential for high water tables and water retention.
- Indicative Floodplain data – indicated seasonal inundation potential.

The above datasets were collated and used to determine the extent of suitable features within each catchment. Any areas that fell outside these criteria but were identified as being wetlands by the presence of a designated protected site were also digitised.

Stage 2 was used to identify major features that may prevent wetland restoration or make an area, identified in stage 1, less suitable. The following features were used to modify the outputs from stage 1:

- Roads (motorways, primary and minor roads)
- Urban Areas (large and small)
- Airports and Airfields
- Landfill Sites (active/inactive)
- Contaminated Land
- Artificial Geology
- Railways

Stage 3 was used to identify topographically discrete, low-lying land. It was also used to exclude areas affected by features not included in the datasets during stage 2 (ie farmsteads and other isolated buildings). Some QA was also undertaken to assess the quality of data in previous stages.

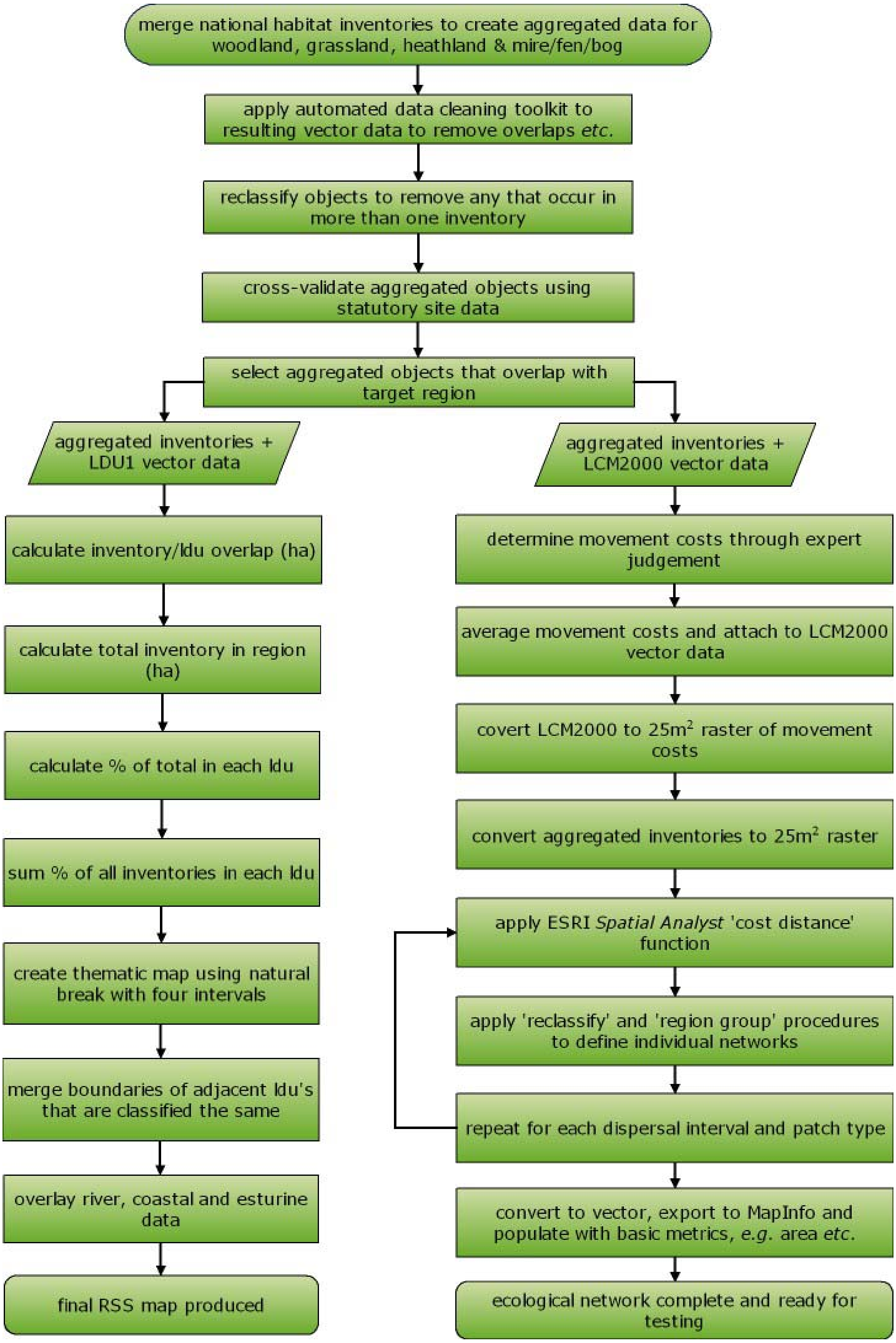
Stage 4 developed a series of selection criteria for identifying areas that might hold the greatest potential. The criteria were based on: water quality, water resource availability, flood regime, designated sites, species data, airport constraint zones, and agricultural land quality.

Selection of priority areas for large-scale river and floodplain restoration, for the RSS, were identified using the outputs from this analysis in combination with the expert judgement. In order to qualify, all categories of river had to provide suitable, contiguous areas greater than 500ha. In addition, prioritisation was given to those areas with least restriction from airport constraint zones, agricultural land quality and water availability.

Further development of the river network methodology is planned so that a more direct evaluation of the physical and ecological continuity can be derived.

Annex 3: Implementation flowchart

West Midlands and Yorkshire and Humber Government Regions



Annex 4: Level 1 Landscape Description Unit attributes

Adapted from Warnock and Diacono (2001).

Physiography (basic form and underlying structure of the land surface)

- **Fluvial lowlands** - flat land associated with waterborne drift, mainly of recent marine or riverine origin, but also including some older lacustrine (lake), or fluvio-glacial drift.
- **Glacial lowlands** - lowland terrain's associated with glacial drift laid down by ice sheets during the Pleistocene period; also includes coastal dunes associated with more recent wind blown drift. (**note:** this category is only used where the drift determines the shape of the surface landform)
- **Soft rocks** - terrain's associated with younger, usually gently folded Mesozoic (Cretaceous, Jurassic, Permo-Triassic) and Tertiary rocks of sedimentary origin.
- **Palaeozoic hard rocks** - terrain's associated with older, often well folded Upper Palaeozoic (Permian, Carboniferous and Devonian) rocks of sedimentary, or igneous origin.
- **Caledonian hard rocks -** terrain's associated with ancient, intensely folded Lower Palaeozoic (Silurian, Ordovician and Cambrian) and earlier Pre-Cambrian rocks of sedimentary, igneous or metamorphic origin.
- **High hills** - elevated, often steeply sloping tracts of high land, mainly over 300 m (1000 ft), with a pronounced upstanding/undulating relief - almost entirely associated with hard (Palaeozoic) rocks in England, with the exception of N. York Moors

land form of underlying geology

- **intertidal flats** - expanses of bare mud, silt, or sand covered by water at high tide.
- **coastal dunes/shingle** - low hills/ridges of sand, pebbles and larger stones piled up by the wind, or by wave action, often forming narrow tracts of land extending along the coast.
- **levels** - extensive areas of flat land, usually at or below sea level, associated with marine/lacustrine drift.
- **vales and valley bottoms -** other flat, or gently rolling land, generally below 120 metres (400 ft) - associated mainly with fluvial, glacial and soft rock sediments in low-lying clay vales, coastal plains and broad valley bottoms.
- **rolling lowland** - areas of intermediate relief, generally below 120 m (400 ft) with a rolling/undulating topography, often including valleys and plateau summits at a greater level of detail - associated mainly with glacial and soft rock sediments, but can also occur in the upland fringe within the hard rock zone.
- **upstanding/undulating** - elevated areas, generally above 120 metres (400 feet), with a pronounced upstanding/undulating topography - usually including valleys and plateau summits at a greater level of detail - associated with both soft rock (chalk, limestone and sandstone) escarpments in the Midlands and southern England and dissected hard rock plateau's in the north and west.
- **steeply sloping** - distinct, often steeply sloping tracts of rising ground, generally well defined by clear breaks in slope - may be in the form of discrete ridges/hills, or escarpment edges.

Ground type – (soil-forming environment)

- **Wetlands** - low-lying land associated with fluvial (marine/riverine) drift and supporting wetland (wet pasture, marsh and fen), or relic wetland vegetation characterised by lines of willow, reeds in ditches, etc. Land may be seasonally or perennially wet, but in many cases groundwater controlled by ditches and pumps.
- **Claylands** - heavy, often poorly draining land associated with base rich clayey and loamy soils developed on soft (Mesozoic and Tertiary) clay and chalky till. Seasonal waterlogging is the main constraint to agricultural production, and although utilised extensively for cereal growing in Eastern England, this ground type is mainly under permanent grassland in central and western areas where damp neutral grassland is the characteristic associated habitat.
- **Other heavy land** - heavy land, typically associated with base poor clayey and loamy soils developed on slowly permeable rocks (mudstones and shales) and mixed till/plateau drift. Seasonal waterlogging is the main constraint to agricultural production, and this ground type is mainly under permanent grassland - patches of wet heath are the characteristic associated habitat, grading into wet moorland at higher elevations in the north and west.
- **Deep loamy soils** - reddish/brown, free-draining mineral soils developed on permeable rocks (limestone, sandstone, siltstone and mudstone), or drift at elevations below about 180 metres (600ft). There are few constraints to agricultural production, other than those imposed by slope and in most areas these soils are intensively cultivated.
- **Chalk and limestone -** light land associated with shallow, free draining soils developed directly on chalk or limestone bedrock - typically distinguished by stony soils with relic calcareous grassland on steeper slopes in soft rock areas and rock outcrops/limestone pavement with dry species rich pasture/hay meadow in hard rock areas.
- **Other light land** - light land associated mainly with sandy/shallow acid brown soils, but also including impoverished (podzolic) soils, developed on permeable rocks (sandstone's, siltstone's and mudstone's), or sandy drift at elevations below about 300 metres (1000ft). Dry acidic grassland and heath are the characteristic associated habitats, but in many areas, particularly in the lowland zone this ground type is intensively cultivated.
- **Moor and bog** - marginal land associated with humic (peaty) and/or nutrient poor mineral soils supporting dwarf shrub heath, acidic grassland and bog habitats, or relic heathy/moorland vegetation (bracken, gorse, etc). This ground type is typically associated with sandstone and igneous rocks in upland/hard rock areas, but also occurs on lowland raised bogs developed on till, or fluvial drift.

*associated habitats that **might** occur within LDU*

- **saltmarsh** - wet coastal habitats associated with vegetated, or partially vegetated silt and mud, periodically covered by the sea at high tide.
- **swamp and fen** - wetland habitats associated with low-lying wet mineral/humic soils which are more or less permanently waterlogged - drained areas are usually distinguished by open ditches/drains with relic wetland species such as reeds.
- **wet pasture/marsh** - wet grassland/marshland habitats associated with low-lying, wet mineral soils which are seasonally waterlogged and/or periodically inundated by water - usually distinguished by occurrence of rushes, tussock grass and other tall flowering plants.
- **damp (neutral) pasture -** damp grassland habitats associated with base rich clayey and loamy soils.
- **dry (rough) pasture** - dry grassland habitats associated with shallow free draining mineral soils - usually distinguished by occurrence of fine leafed grass species, often in association with an abundance of low flowering herbs and/or bracken.
- **heath/moor** - dwarf shrub habitats (excluding wet heath and bog), often intermixed with dry acidic grassland, associated with impoverished (podzolic) soils - relic heathland areas are typically distinguished by an abundance of gorse and bracken.
- **wet heath/bog** - wet moorland habitats associated with humic upland soils which are more or less permanently waterlogged - these habitats often survive as extensive tracts of uncultivated land (raised, valley and blanket bog) in upland areas.
- **disturbed land** - vegetated, or partially vegetated mounds/small hills of rock waste produced as a by-product of the mining industry - particularly prevalent in former coal mining areas, but also associated with china clay, brick clay and cement industries.

Settlement pattern – (arrangement of historic human settlement)

- **Nucleated** - rural landscapes characterised by discrete settlement nuclei (large single villages and/or smaller township clusters) associated with a low level of dispersal - there is a strong association between this type and the former extent of medieval common field systems, especially within the 'planned' zone of central England.
- **Settled** - rural landscapes characterised by multiple settlement nuclei (villages, hamlets and/or wayside clusters) associated with a moderate to high scattering of farms and outlying dwellings - typically distinguished by frequent place names ending in 'Green', 'End', 'Heath', 'Houses', etc.
- **Dispersed** - sparsely settled rural landscapes characterised by isolated farmsteads and occasional rural dwellings - frequently distinguished by place names indicating enclosure from woodland or ‘waste’ (eg 'Marsh', 'Moor', 'Heath', etc).
- **Wildland** - extensive areas of uncultivated, mainly unenclosed land (including moorland, heath and coastal grazing marsh) characterised by the virtual absence of human habitation.
- **Urbanised** - semi-rural areas (eg the coalfields of Derbyshire) where the rural settlement pattern has been significantly modified as a direct consequence of large-scale industrial activity.
- **Urban** - extensive areas of predominantly built land where the rural settlement pattern has been completely subsumed by urban development (see urban land use) - lines have been rationalised to physiographic boundaries in places.

current pattern of rural settlement

- **large/single villages** - village landscapes characterised by a single, usually large parish settlement.
- **township clusters** - village or settled landscapes characterised by parishes with multiple township nucleation's, in the form of hamlets and/or small villages.
- **wayside dwellings** - settled landscapes characterised by frequent loose clusters of dwellings strung out along roads and lanes.
- **scattered farms/dwellings -** settled rural landscapes characterised by thinly scattered farmsteads and rural dwellings - usually associated with an irregular network of winding lanes.
- **planned farms** - sparsely settled rural landscapes characterised by isolated farmsteads and occasional wayside clusters - typically associated with an ordered pattern of lanes and rectilinear fields with mainly straight boundaries.
- **meadowland** - unsettled river corridors and other tracts of low-lying land that are periodically inundated by water.
- **unsettled** - other land characterised by the virtual absence of human habitation.

Landcover (woodland cover and land use)

- **Ancient wooded** - well wooded landscapes (usually greater than 10% cover) characterised by large blocks and/or or clusters of woodland, mainly of ancient origin (as defined on the ancient woodland inventory), which pre-date the surrounding enclosure pattern - often associated with areas of heavy clay soils, or steeply sloping ground.
- **Secondary wooded** - well wooded landscapes (usually greater than 10% cover) characterised by recent - in historical terms - secondary and/or large plantation woodlands/belts of trees which are often superimposed unconformably on a pre-existing unwooded landscape - typically associated with sandy soils (lowland heath) in soft rock zone and impoverished mineral/humic soils (moorland) in hard rock zone.
- **Trees and woods** - agricultural landscapes characterised by a mixture of scattered, often dense, hedgerow trees (typically oak) and small irregularly shaped woods, mostly of ancient origin (as defined by the ancient woodland inventory) - typically associated with areas of dispersed settlement.
- **Arable other trees** - arable/mixed farming landscapes characterised by thinly scattered/groups of trees and/or game coverts - typically associated with areas of nucleated settlement.
- **Pastoral other trees** - pastoral landscapes characterised by thinly scattered/groups of trees and/or game coverts.
- **Open/unenclosed land** - treeless, usually uncultivated, tracts of open land where natural constraints (climate and/or soils), or traditional management practices, generally preclude the establishment of tree cover.
- **Urban** - cities and other large built up areas greater than 10 km^2 in extent.

broad land use pattern

- **market gardening** - settled agricultural landscapes characterised by horticultural production, often in association with orchards and/or hop gardens.
- **general cropping** - dominance of arable farming (>70 % arable cultivation), typically characterised by a mixture of cereals and other crops.
- **mixed farming** - settled agricultural landscapes, characterised by mixed arable and livestock farms (30 - 70% of agricultural land utilised for arable cultivation).
- **dairying -** settled pastoral landscapes (<50 % of agricultural land utilised for arable cultivation) dominated by dairying - often associated with mixed livestock and arable farming in soft rock zone.
- **stock rearing** - settled pastoral landscapes, typically dominated by cattle and sheep rearing, but also including horse grazing (>70 % of agricultural land utilised for grassland production) - often associated with mixed livestock and arable farming in soft rock zone.
- **rough grazing** - seasonal grazing of rough pasture on marginal (uncultivated) land.

Annex 5: Local stakeholder representation

Yorkshire and Humber Government Region stakeholders

Royal Society for the Protection of Birds
English Nature
Sheffield Wildlife Trust
Environment Agency
Yorkshire Wildlife Trust
Lincolnshire Wildlife Trust
Countryside Agency
Government Office for Yorkshire and the Humber
Yorkshire and Humber Regional Development Agency
North Yorkshire County Council
Yorkshire Dales National Park
Leeds City Council
Rural Development Service

Annex 6: Estimated movement costs

Relative costs to movement as determined through expert judgement (lowest cost=1and highest=50).

broad land cover type	specific land cover type	woodland	heathland	mire/fen/bog	grassland
	sea	50	50	50	50
	water (inland)	40	50	20	50
Littoral rock	rock	50	50	50	40
	rock with algae	50	50	40	40
Littoral sediment	mud	50	50	50	30
	sand	50	20	40	20
	sand with algae	50	40	40	20
Saltmarsh	saltmarsh	45	50	50	30
	saltmarsh (grazed)	50	50	50	30
Supra-littoral rock	rock	45	50	50	40
Supra-littoral sediment	shingle (vegetated)	45	50	50	20
	shingle	45	50	50	25
	dune	20	5	30	10
	dune shrubs	15	3	30	15
	bog (shrub)	20	3	1	30
	bog (grass/shrub)	25	1	1	20
	bog (grass/herb)	25	1	1	15
	bog (undifferentiated)	25	1	1	25
	dense (ericaceous)	20	1	10	30
	gorse	15	1	20	10
	open	25	1	5	10
Montane habitats	montane	20	40	30	20
	deciduous	1	40	50	10
	mixed	1	40	50	15
	open birch	1	20	30	10
	scrub	1	20	40	5
	conifers	5	10	40	10
	felled	3	3	30	5
	new plantation	5	3	30	20
	barley	35	50	50	50
	maize	35	50	50	50
	oats	35	50	50	50
	wheat	35	50	50	50
	cereal (spring)	35	50	50	50
	cereal (winter)	35	50	50	50
	arable bare ground	35	50	50	45
	carrots	35	50	50	50
	field beans	35	50	50	50
	horticulture	35	50	50	50
	linseed	35	50	50	50
	potatoes	35	50	50	50
	peas	35	50	50	30
	oilseed rape	35	50	50	30
	sugar beet	35	50	50	30
	unknown	35	50	50	50
	mustard	35	50	50	50
	non-cereal (spring)	35	50	50	50
	orchard	25	50	50	10
	arable grass (ley)	30	50	50	40

broad land cover type	specific land cover type	woodland	heathland	mire/fen/bog	grassland
	setaside (bare)	30	50	50	40
	setaside (undifferentiated)	25	50	50	40
Improved grassland	intensive	35	50	50	50
	grass (hay/ silage cut)	30	50	50	10
	grazing marsh	30	50	40	5
Setaside grass	grass setaside	25	50	40	5
Neutral grass	neutral grass (rough)	20	50	50	3
	neutral grass (grazed)	25	50	40	2
Calcareous grass	calcareous (rough)	25	50	50	2
	calcareous (grazed)	25	50	40	1
Acid grass	acid	20	10	40	1
	acid (rough)	20	20	20	2
	acid with *Juncus*	20	20	5	2
	acid *Nardus/Festuca/Molinia*	20	5	10	2
Bracken	bracken	15	50	50	3
Fen, marsh and swamp	swamp	20	50	1	10
	fen/marsh	20	50	1	5
	fen willow	5	50	5	5
Suburban/rural developed	suburban/rural developed	10	50	50	45
	urban residential/ commercial	30	50	50	50
	urban industrial	35	50	50	50
Inland Bare Ground	despoiled	30	50	50	10
	semi-natural	25	50	50	1

Example of how movement costs might be estimated for woodland species.

Ecological cost	Land cover type	Movement costs (as a function of distance for a 1km network)
LOW	eg broadleaved deciduous woodland	1 – high permeability max. dispersal distance = 1000 ecological cost = 1 movement 1000/1=1000m
	eg broadleaved scrub	3 - medium high permeability max. dispersal distance = 1000 ecological cost = 3 movement 1000/3= 333m
MEDIUM	eg bracken	10 - medium permeability max. dispersal distance = 1000 ecological cost = 10 movement 1000/10= 100m
HIGH	eg rough neutral grassland	20 - medium low permeability max. dispersal distance = 1000 ecological cost = 20 movement 1000/20= 50m
	eg arable - cereals	50 – low permeability max. dispersal distance = 1000 ecological cost = 50 movement 1000/50= 20m

Adapted from:

WATTS, K., GRIFFITHS, M., QUINE, C., RAY, D., & HUMPHREY, J.W. 2005. *Towards a woodland habitat network for Wales.* Contract Science Report, 686. Bangor: Countryside Council for Wales.

Research Information Note

English Nature Research Reports, No 687

Planning for biodiversity – opportunity mapping and habitat networks in practice: a technical guide

Report Authors: Dr Roger Catchpole Date: May 2006
Keywords: ecological network, article 10, spatial planning, biodiversity, landscape character, GIS, opportunity mapping

Introduction

This work has been undertaken to try and provide a bridge between science and practice. It has attempted to demonstrate how first principles might be applied to existing information in order to try and deliver a standardised, ecologically robust starting point for the delivery of both regional and local spatial planning. In doing this it has not only provided a framework for strategic environmental enhancement across large areas but it has also informed a number of Regional Spatial Strategies (RSS). At a smaller scale it has evaluated the potential landscape permeability between sites. This has been essential in developing a credible response to obligations to define and manage networks of habitat.

What was done

The work relied on widely available information sources that included national habitat inventories, Landscape Description Units (level1) and Land Cover Map 2000. The analysis was based on two different approaches. The first utilised a landscape characterisation framework to package biodiversity information. The second utilised site-based information to indicate the degree of functional connectivity between sites. This work was undertaken in partnership with regional biodiversity forums. The products were distributed to English Nature staff and selected local record centres between 2005 and 2006.

Results and conclusions

The results provide spatially referenced indicative habitat networks, at three different dispersal intervals, for woodlands, heathlands, grasslands and mires/fens/bogs. A series of biogeographic summaries were also produced for a number of regions that have since provided the basis for strategic, environmental enhancement maps for two RSS submissions. The habitat network analysis will be used to create planning guidance to help frame Local Development Frameworks (LDF) and Green Infrastructure Planning (GIP) in one region. The work successfully demonstrated how strategic, character-based frameworks can be used, in conjunction with biodiversity information, to set realistic environmental objectives. At the level of the individual site, this work has also demonstrated how the degree of connectivity, that might be present between similar habitats, can be evaluated and how clusters of sites might function as a wider network.

Continued……

English Nature's viewpoint

The methodology makes a direct and pragmatic contribution to setting ecologically robust frameworks for the delivery of Regional Spatial Strategies, Local Development Frameworks, Green Infrastructure Planning, Local Biodiversity Action targeting, climate change adaptation and future agri-environment targeting. The different approaches have now been demonstrated across a number of different regions. The strategic, biogeographic analysis is potentially available to all regions while the patch-based analysis is currently available in only two. The availability of the site-based analysis will be extended to cover the whole of England. Neither approach is intended as a replacement for existing initiatives but as something that will provide a common starting point for local action as well as a consistent response to strategic issues such as habitat fragmentation and climate change.

Selected references

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Top left: Using a home-made moth trap.
Peter Wakely/English Nature 17,396
Middle left: Co_2 experiment at Roudsea Wood and Mosses NNR, Lancashire.
Peter Wakely/English Nature 21,792
Bottom left: Radio tracking a hare on Pawlett Hams, Somerset.
Paul Glendell/English Nature 23,020
Main: Identifying moths caught in a moth trap at Ham Wall NNR, Somerset.
Paul Glendell/English Nature 24,888