Lancashire Ecological Network Approach and Analysis (Version I)

This report was prepared by The Wildlife Trust for Lancashire, Manchester & North Merseyside (LWT) and Lancashire Environment Record Network (LERN) on behalf of the Lancashire Local Nature Partnership with funding from Natural England. The majority of the analysis was undertaken during 2013.

Caveat

Results from the Wetland and Heath ecological network analysis need further refinement and should be treated as draft at this stage.

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Contents

Background

Policy and Legislative Background to Ecological Networks

England has a wide range of different types of statutory and non-statutory designation for habitat protection.

Sites can be segregated into three levels based on their purpose and level of protection offered (Lawton 2010)

- Sites with a primary purpose of nature conservation and which have a high level of protection due to statutory status or ownership (*e.g.* Natura 2000 sites, SSSIs and nature reserves).
- Sites designated for their high biodiversity value but which do not receive full statutory protection (*e.g.* Local Wildlife Sites, known in Lancashire as "Biological Heritage Sites")
- Areas designated for landscape, culture, and/or recreation and with wildlife conservation included in their statutory purpose (*e.g.* Arnside & Silverdale and Forest of Bowland AONBs)

Sites alone are insufficient for protecting the species, ecosystems, and ecosystem processes found in England's landscapes. To accommodate these dynamic, natural phenomena the need to plan for the protection and management of ecological networks has been recognised. Several recent efforts have led to increased focus on ecological networks.

- Professor Sir John Lawton led a panel and produced a report reviewing England's Wildlife Sites and Ecological Network (Lawton *et al*. 2010). This study concluded that, on their own, England's wildlife sites do not comprise a coherent and resilient ecological network. The report outlines a series of approaches, some of which have now been incorporated into Government planning efforts, for establishing a coherent and resilient ecological network.
- The National Planning Policy Framework (2012) (NPPF) requires local authorities to take a strategic approach to biodiversity. Local Plan policies should "*plan for biodiversity at a landscape-scale across local authority boundaries; identify and map components of the local ecological networks...planning positively for the creation, protection, enhancement and management of networks of biodiversity.*" Furthermore, local plans have historically been charged with promoting the preservation, restoration, and re-creation of priority habitats, and the protection and recovery of priority species populations.

Development of the Lancashire Ecological Network, and the accompanying framework reports, is a local response to Government targets for halting biodiversity loss and safeguarding ecosystem goods and services. It will enable local planning authorities in Lancashire to address the requirements in the National Planning Policy Framework (NPPF).

The objective is to identify likely ecological connections between existing core sites and to aid in the identification of areas that support ecosystem processes and species populations that are not within core sites but are critical for the establishment of a functioning ecological network.

What is an Ecological Network?

An ecological network is a collection of suitable habitat patches connected by movement corridors through the intervening habitat matrix. The development of an ecological network as a conservation strategy is intended to maintain the function of the ecosystem in order to support the conservation of species and habitats while also promoting land management strategies that limit the impacts of human activities on biodiversity.

This project describes two primary components of the ecological network – core sites and corridors. Corridors may take one of three primary forms – linear corridors (*e.g.* hedgerows, woodland strips, rivers, streams & ditches); stepping stones (small patches of intact habitat that provide shelter, feeding, and resting opportunities); and landscape corridors (mixed habitat types that allow species to move between habitat patches).

For this project, the core sites have been identified as those areas occurring within sites of ecological importance at the international, national, or county levels. These sites vary widely in their size and management approach; with some sites being small and intensively managed, while others are extensive. While some sites have active management plans, at many the current management is insufficient to halt habitat degradation and species loss. One cause of ineffective management at these sites is a failure to identify and address the threats that face each site. Furthermore, sites have been identified for a wide variety of reasons: some are identified for a single habitat or species, while others support a diverse range of habitats and/or species.

The ecological theory underpinning habitat corridors has evolved over time, but was initially informed by MacArthur and Wilson's (1967) theory of island biogeography. This observed and asserted that the number of species in insular habitats is dependent on distance-dependent colonisation and area-dependent extinction. This theory predicts that smaller and more isolated habitats will support fewer species. Jared Diamond (1975) translated this theory into simple guidance for reserve management (Figure 1).

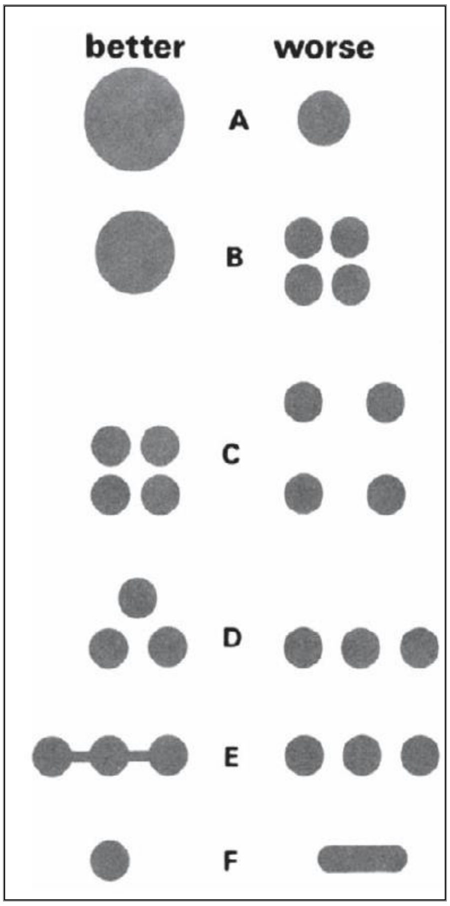


Figure 1. Suggested geometric principles, derived from island bio-geographic studies, for the design of nature reserves.

In each of the six cases labelled A to F, species extinction rates will be lower for the reserve design on the left than for the reserve design on the right. Diamond (1975)

Meta-population theory (*e.g.*, Hanski and Simberloff 1997) advanced the thinking further by recognising the importance of patchy habitats, extinction and colonization. However, it assumes a network of small patches that interact with one another as individuals (and species) move from patch to patch. This theory emphasizes the importance of dispersal, as local extinction events are predicted to occur in patches throughout the landscape. Dispersal is the mechanism that prevents regional extinction by allowing patches to be repopulated and for populations to be sustained in patches where local populations are not self-sustaining.

These, and related theories, generate spatially explicit models that may be used to evaluate the landscape in order to develop conservation strategies to maintain or improve the condition of species and habitats. While models can provide valuable feedback to planners, spatially explicit models can be overly sensitive to parameters that are either poorly known or impossible to measure (Ruckelshaus *et al.* 1997). Furthermore, while corridors may improve population persistence at the regional scale (Breir and Noss 1998), corridors may not be sufficient to mitigate for the overall losses and fragmentation of habitat (*e.g.,* Fahrig 1998 and Rosenberg *et al.* 1997).

Habitat Connectivity and Fragmentation

Ecological networks are one of the conservation tools developed to respond to challenges created by habitat loss and fragmentation. Several factors contribute to habitat loss, degradation and species declines. UK society's responses to many of these changes has often been piecemeal – designed only to protect specific charismatic species or to arrest dramatic changes in particular wildlife populations.

For example, habitat loss and species declines led to identification of protected areas. In Great Britain & Ireland this dates back to the early 20th Century and the activities of Charles Rothschild and others. Protected areas have been designated without the benefit of a coherent regional or national strategy to guide ecological function and recovery, simply highlighting natural resources in need of protection. However, many species have continued to decline because sites are too small, capturing only a portion of the habitats on which particular species rely; or sufficient in size to support only a reduced population; or inappropriately or inadequately managed; or any or all of those. Furthermore, protected areas in isolation act as habitat islands and are likely to be insufficient to prevent future species declines.

As the protection of individual sites or species is, in many cases, not succeeding in preventing declines in biodiversity, designation and management of groups or systems of nature reserves has been a focus of multiple environmental initiatives throughout the world (*e.g.*, Bennett 2004). Focusing on ecological networks rather than specific core sites allows planners and land managers to consider the landscape context of core sites and landscape heterogeneity, as well as broad ecological patterns and processes (*e.g.*, Noss and Harris 1986).

The preferred strategy for protected sites is to have many, large, connected sites. The theoretical basis for this is:

- Small sites are often unsustainable and populations can be lost due to uncontrollable and random factors (small sites tend to support smaller populations than larger sites)
- Small sites are susceptible to damage from adjacent land uses, so-called 'edge effects' – from which larger sites are somewhat insulated
- Connected sites allow for movement of individuals, repopulating and avoiding inbreeding issues.

A group of core areas that are linked and buffered from threats will improve the viability of ecosystems and species populations. Consequently, enhanced ecological connectivity may increase the ability of the protected areas to support species populations. Such ecological connections may provide for:

- Movement corridors between sites
- Movement corridors between breeding and feeding areas
- Access to feeding opportunities
- Dispersal of offspring (repopulating sites where populations have disappeared and/or supporting populations that are not sustainable in isolation).
- Reduced inbreeding (facilitating exchange of genetic material)
- Increase in fitness of species (enhancing survival chances and reproductive success)
- Access to (alternative) breeding grounds

Collectively, these make populations more resilient to long- or short-term changes, whether those arise as a consequence of land management, development or climate change.

Ecological Networks

As landscapes are progressively managed or developed, the area available for species that rely on natural and semi-natural habitat types shrinks. The development of tools to identify and protect sites of special conservation interest at the local, national and international scale are part of efforts to identify areas currently used by species of conservation interest. However, in our modern landscapes, competing demands on ecosystem services mean that these sites are seldom of sufficient size on their own to support self-sustaining populations of most species.

It is, therefore, important to consider the relationship between sites identified for protection and also to consider how species may use the intervening landscape where no special habitat protections may exist. Similarly, these analyses may highlight particular sites and/or corridor linkages that are of particular importance to the functioning of the network.

These connections may allow offspring to disperse to new habitat patches as a site approaches its carrying capacity, and/or for immigrants to re-establish populations that had disappeared within a patch.

Climate change may result in habitat changes that make currently suitable habitat uninhabitable in the future, creating an impetus for species dispersal across the landscape to new habitat patches. Dispersal of this sort will rely on habitat corridors for the movement of populations over long periods of time.

The purpose of this project is to:

- Identify the intact, natural and semi-natural landscape connections between existing protected areas
- Evaluate how species may move through the landscape between identified sites of conservation interest (core sites)
- Consider how the ecological network, which includes both the sites and the ecological corridors and stepping stones connecting them, function
- Recommend future management and monitoring activities for the ecological network

Modelling the Lancashire County Ecological Network

Discussion

Mapping landscape corridors that connect core sites has been an area of substantial scientific inquiry, and there are multiple ways to approach the challenge (*e.g.*, Noss and Harris 1986).

Modelling ecological networks can be done for either individual ('focal' or 'target') species or for natural areas (habitats or sites).

Modelling individual species requires sufficient scientific knowledge about species' preferences, and that sufficient data are available to support spatial modelling. Ultimately, the results may be specifically tailored to that species and its needs and may not be applicable to other species or ecosystems. Therefore, care must be taken in the species chosen, and often several species are modelled to create an 'umbrella' (or 'generic focal species') that captures the range of species' needs, thereby acting as a surrogate for a group of species. Conceptual models of habitat preferences for a number of species have been developed (*e.g.*, Watts *et al*, 2010): some of these species are found in Lancashire.

The alternative is to model landscape integrity by characterizing the habitat condition and level of modification in modelling connections between sites. One advantage is that this type of approach requires fewer data and less knowledge about species' habitat associations or behaviour than species-based approaches (Theobald 2010). Ultimately, an integrity-based approach is a coarse filter for identifying areas for species and/or for ecological processes that may be sensitive to human disturbance.

The Lancashire Approach

The Lancashire Ecological Network approach focuses broadly on ***landscape integrity*** (*i.e.* areas that have lower levels of human modification and are in relatively natural condition). This approach identifies ecological connections between areas that contain natural or semi-natural habitats and have been identified as ecologically significant (*i.e.* as 'wildlife sites'). This approach assumes that species will use similar habitats within core sites and within corridors and therefore seeks to identify corridors of relatively intact habitat to connect core sites. Protecting natural and semi-natural landscapes may provide an effective coarse-filter strategy (Noss 1996) for protecting most of Lancashire's biological diversity. However, this strategy should continue to be complemented by other efforts tailored towards addressing the specific needs of communities and populations that are deemed to warrant special consideration.

Conceptually, species moving through unfavourable habitats are exposed to increased threats from adjacent land uses and may encounter barriers to movement. By mapping and evaluating likely movement corridors potential threats can be identified and managed, and barriers can be removed or managed.

Connections were modelled for three groupings of priority habitats and the species:

- Woodland and Scrub;
- Grassland;
- Wetland and Heath.

Due to their linear and continuous nature, rivers and streams are assumed to form a natural network with the shorelines constraining the network. Rivers and streams should, however, be a focus of further investigation for the identification and correction of water quality issues, barriers (weirs) and other hard engineering (culverting, channelisation *etc*). A lack of available, detailed, spatial data regarding rivers and streams prevented further analysis of associated features and areas of intact habitat during this stage of network identification. Furthermore, some studies have suggested that physical properties associated with water-bodies may strongly influence the movement of organisms (*e.g.*, Michels *et al* 2001).

Modelling the Ecological Network requires identifying existing protected areas (Core Areas), mapping habitat throughout the study area, creating assumptions about how species associated with each habitat might use the habitat within the study area, and using this information to map connections between core sites.

Cross-boundary Connections

The landscape-scale approach required sites and habitats outside the county boundary to be considered in the analysis. The study area (Figure 2) therefore extended to a 5km buffer around Lancashire, extending into eight other LNP areas (Figure 3).

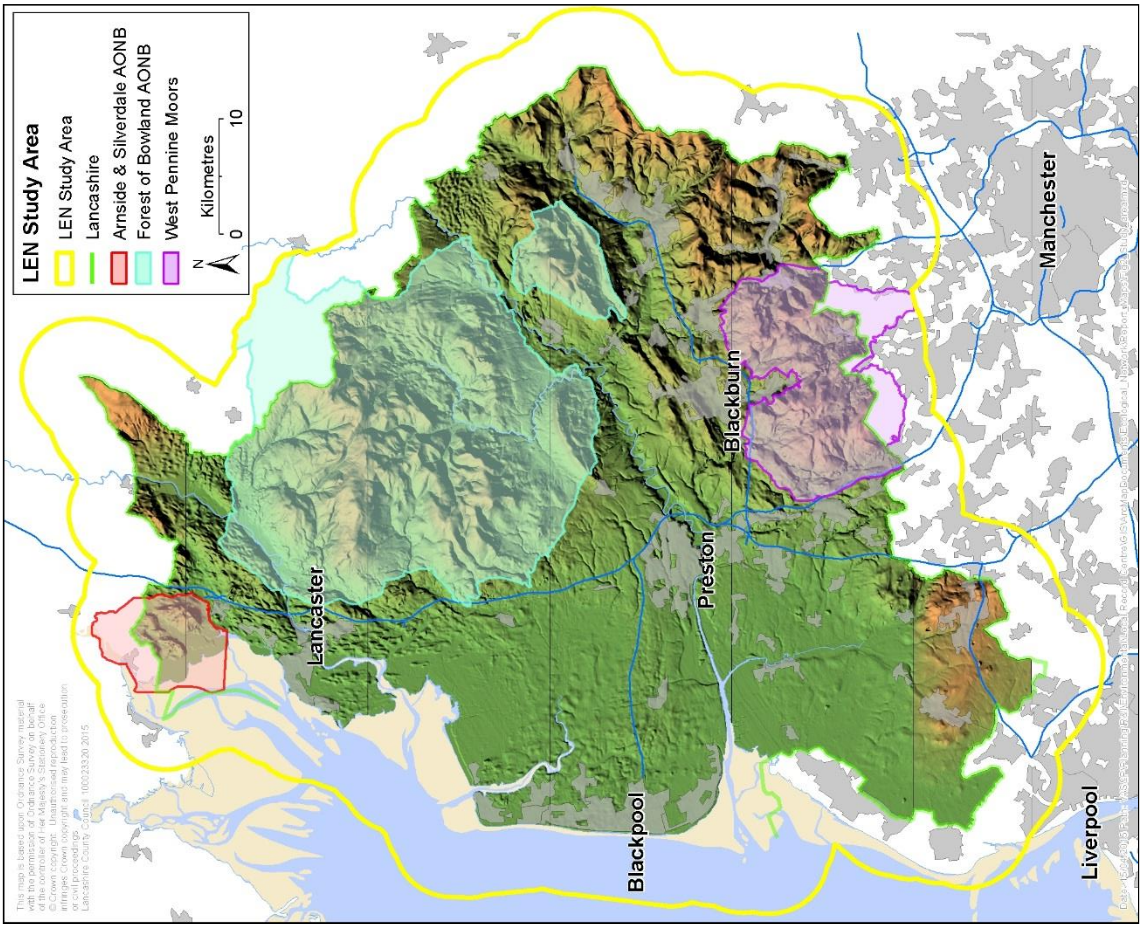


Figure 2. Map showing the Lancashire Ecological Network Study Area

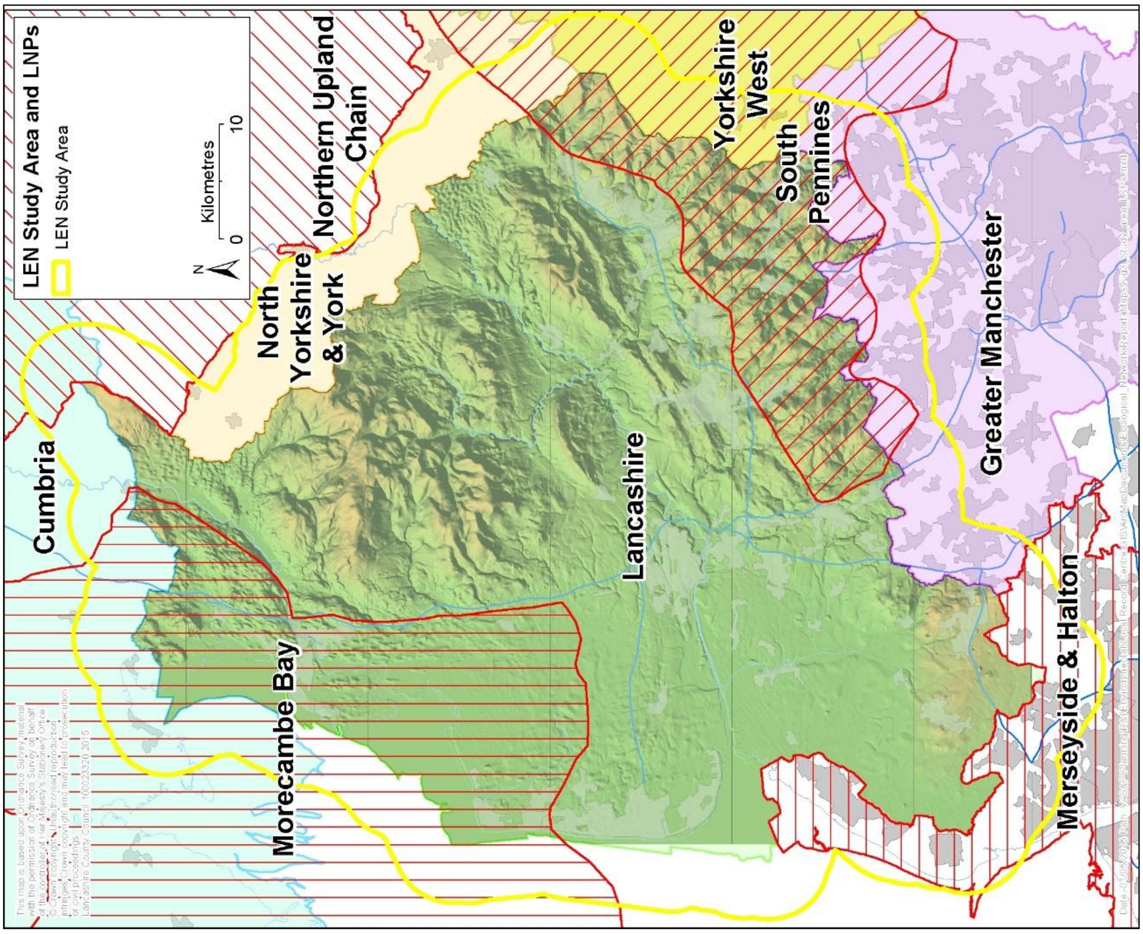


Figure 3. Map showing the Lancashire Ecological Network Study Area in relation to Local Nature Partnership boundaries.

Table 1. Summary of GIS spatial data layers used for habitat connectivity modelling.

Spatial Layer	Summary
Land Cover/Land Use	In the absence of up-to-date field survey for the whole study area, a composite habitat layer was created drawing upon the elements of a number of different digital datasets. The Phase 1 Habitat Survey, which included field observations throughout Lancashire collected prior to 1991, was supplemented with sites-based habitat surveys and data derived from imagery, and in Land Cover Map 2007 and the National Forest Inventory. These datasets were used to complement the short-comings of each. The Phase 1 dataset was collected on the ground by trained observers. However, its date of collection means some observations may no longer reflect the ground conditions. The Land Cover Map 2007 and the National Forest Inventory provide a systematic overview of habitats. However, both are derived from an interpretation of remote sensing and there are some consistent biases in the data.
Roads	This identifies road centre-lines and categorises them by class (Motorway, Trunk Road, 'A' Road *etc*).
Housing and structures	This identifies all building outlines and buffers these by 33.3m (100ft).
Existing protected areas	These comprise Natura 2000 sites, SSSIs and county wildlife sites. Sites were classified as supporting one or more broad habitat types.
Species Observation Data	LERN maintains a dataset of species observations, by credible observers, of Priority and other species.

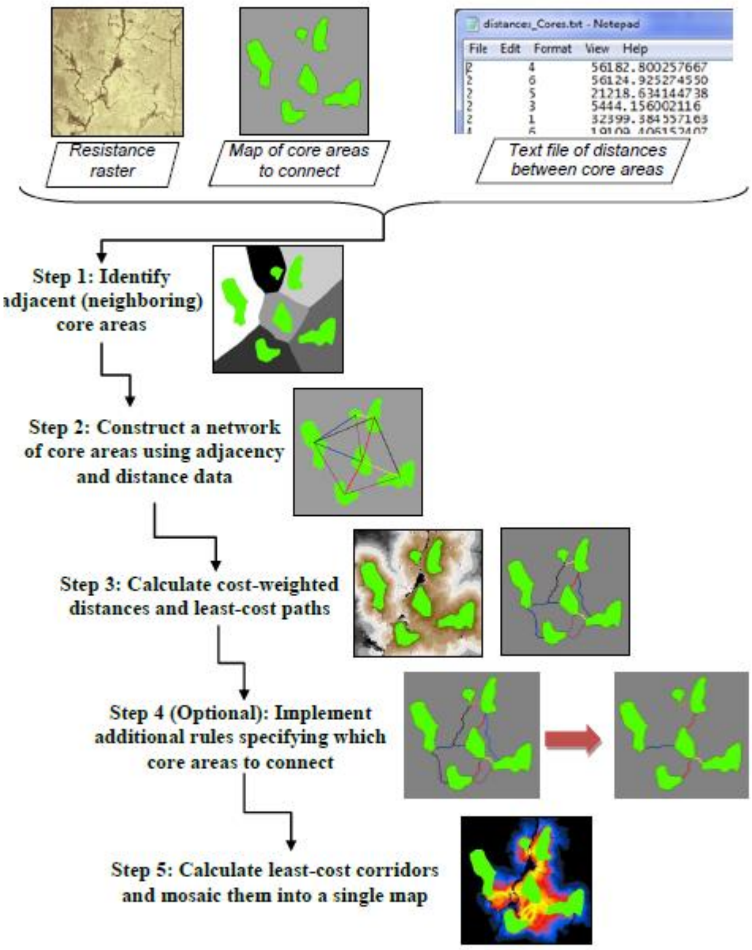
When considering existing protected areas, most are not totally isolated and surrounded by an "ocean" of non-habitat. The quality and types of habitat in the study area may be critical to determining just how isolated protected areas are (*e.g.*, Ricketts 2001).

Methodology

The method described here relies on two primary input datasets and then uses computational analysis to identify the connections between core sites. The two primary inputs are 1) boundaries of identified 'core' sites, and 2) a resistance dataset that characterizes the 'ecological cost' to species of moving through the landscape. The resistance dataset could also be characterized as a form of semi-quantitative, habitat suitability mapping - where lower resistance values represent better habitat conditions and higher values represent ecological barriers to movement, or non-habitat. The resistance dataset is created by combining habitat quality information with measures of human modification and disturbance (proximity to houses and structures and to highways).

This analysis relies on the Linkage Mapper tool to identify ecological connections (McRae and Kavanagh 2011). This tool automates several standard routines within ESRI's ArcGIS to identify least-cost paths between core sites (Figure 4). Least-cost paths are the lowest cost route between two adjacent core sites where the cost of moving through the landscape is calculated using the resistance dataset. In addition to identifying the specific path between two sites, the analysis gives each habitat cell (25m x 25m) in the study area a value representing the ecological resistance cost of moving from that cell to one of the core site pairs. The analysis then combines the corridor-mapping for all pairs of sites evaluated to create a mosaic corridor-map which is a composite of all linkage-maps created for the study area such that each habitat cell represents the minimum value of all corridor-layers. This mosaic of corridors allows us to identify those corridors predicted to have the greatest likelihood of use by a generic species associated with the habitat under analysis.

Figure 4. Overview of steps involved in creating ecological corridors using Linkage Mapper (from McRae and Kavanagh 2011).



Limitations of the Current Methodology

Despite the recognition that the resistance of the habitats in the landscape to species' movements is critically important to determining how well-connected an ecological network may be, there are few empirical studies of habitat-resistance that can be applied. Studies have shown that species have higher rates of movement across native habitats than other habitat types (*e.g.*, Pither and Taylor 1998 and Robinson *et al.* 1992). However, these differences will be likely to differ amongst even closely-related species.

In general, differences in species' ability to move through a given habitat are likely to be related to whether such species are habitat-specialists (or obligates) that are found solely or primarily in a single habitat-type or are reliant on a single habitat for food, shelter or reproduction; or generalists that are able to use a broad range of habitats to support their needs.

Like all analyses, the outputs of this process are dependent on the quality and resolution of the data used to support the analysis, and the assumptions applied to that data. In this report, we have attempted to be transparent about the assumptions that have been made in using the data and in describing how those assumptions may affect outputs. However, we are aware of limitations in input data which may affect the analysis in predictable ways. Some habitat elements are simply too small to be captured by the mapping efforts to date. For example, hedgerows and tree-rows that are common along field and parcel boundaries are believed to provide movement corridors for some species (*e.g.*, Hinsley *et al* 1995). However, these characteristics of the landscape have yet to be captured electronically for Lancashire LNP area.

Furthermore, these analyses provide predictions for how the *ecological network* may be functioning. For *individual* organisms and species the perception of an ecological network will vary. Habitat-generalists and habitat specialists are likely to perceive the landscape in different ways. This will affect how each moves through the landscape. Our analysis has concentrated on evaluating specific habitat-types that are known to have suites of associated habitat-specialists. Habitat-suitability scores for the landscape have been developed with regard to those species' specialisms. Due to inherent differences in the movement-capabilities of species using the ecological networks described in this report, we have not attempted to constrain the description of the network to a specific scale, but instead to identify descriptive information about the network which can be interpreted by considering the needs and abilities of different species as appropriate. There are, at least, three contexts for evaluating the relationship of core areas to the ecological network, cores may:

1. be large or productive - in which case they are likely to produce surplus species-offspring that could disperse across the landscape (*e.g.*, source/sink meta-populations as described by Pulliam (1988));

2. be well-connected to other sites and therefore provide intermediate connections or *refugia* between core sites, even if these are not particularly large (*e.g.* dispersal among habitat fragments); and
3. provide a bridge or stepping-stone connecting otherwise disconnected elements of the landscape (*e.g.* the 'spreading of risk' meta-population model (den Boer 1968, Levins 1969)).

Identifying Functional Habitat Connectivity

The idea of 'connectivity' between patches or within an ecological network depends on the distance between habitat patches, the presence of movement-corridors, and the resistance of the matrix to species' movements.

As previously outlined above (page 6), the Lancashire Ecological Network seeks to identify linkages between known wildlife sites. It comprises a series of individual networks identified for three groupings of priority habitats:

- Grassland
- Woodland and Scrub
- Wetland and Heath

These groups were defined with reference to priorities identified in the Lancashire Biodiversity Action Plan and in the light of restrictions imposed by the current habitats dataset. Each wildlife site was assigned to one or more habitat groups where the reasons for the site's identification relate to that habitat group.

The relationship between the network habitat groups, the Lancashire BAP, and priority habitats is identified in Table 2 below.

Table 2. The relationship between the Lancashire Ecological Network habitat groups, the Lancashire BAP, and priority habitats.

Lancashire Ecological Network Habitats Grouping	**Lancashire Biodiversity Action Plan: Habitat Plan Name**	**Priority Habitats** Natural Environment & Rural Communities Act 2006, Section 41
Grassland	Calcareous Grassland Species-rich Neutral Grassland	Lowland calcareous grassland Lowland meadows Purple moor-grass and rush pastures Upland calcareous grassland Upland hay meadows Coastal sand dunes
Wetland and Heath	Mossland Reedbed Moorland/Fell	Purple moor-grass and rush pastures Lowland heathland Upland heathland Blanket bog Lowland fens Lowland raised bog Reedbeds Wet woodland
Woodland and Scrub	Broadleaved and Mixed Woodland	Lowland beech and yew woodland Lowland mixed deciduous woodland Upland mixed ashwoods Upland oakwood Wet woodland Wood-pasture and parkland Limestone pavements

Habitat Group Elements

We have attempted to classify elements of the network analysis in terms of the requirement for local planning authorities to comply with the National Planning Policy Framework. To this end we have identified the following elements for each habitat group:

- Core Areas

  Core Areas are identified wildlife sites of at least county importance. All Core Areas are classified by the priority habitat groupings for which they are of importance.

- Corridors

  Corridors comprise continuous stretches of permeable habitat that can, over time, be utilised by species to move between Core Areas. Corridors are further classified by distance between similar core areas.

- Stepping Stones

  Stepping Stones are sites of local ecological importance and areas of Priority Habitat within or adjacent to corridors. Stepping Stones are classified by habitat and relationship to other network elements.

Existing core sites are assumed to have been identified to protect species and ecosystems. Habitats are mapped for the entire study area. Resistance values are established for each habitat based on the relative intactness and similarity of species assemblages found in each habitat to the target habitat-group.

Resistance Metrics

Table 3a. Grassland resistance weightings.

Grassland Species Habitat Resistance Ratings		
Habitat Grouping used in Weighting	**Value**	**LEN Habitat Mapping Class**
High diversity, semi-natural grasslands	1	Acid grassland Calcareous grassland
Low diversity, semi-natural grasslands	5	Neutral grassland Rough acid grassland Rough calcareous grassland Rough grassland Rough neutral grassland
Wetland & Heath	20	Wetland and heath
Scrub	25	Scrub or young trees
Other semi-natural	25	Other semi-natural
Improved and Agriculture Uses	30	Amenity grassland Arable and horticulture Improved grassland
Parklands	50	Parklands
Developed areas	50	Built-up areas and gardens
Plantation woodlands	60	Coniferous woodland Mixed woodland
Semi-natural woodlands	75	Broadleaved woodland
Exposed and rocky	90	Bare ground Coastal above MHW Coastal rock Littoral sediment Rock habitats Shingle
Water (Lakes, estuary and saltwater)	999	Flowing water Littoral sediment Outside Study Area Standing and flowing water Standing water Tidal water
Modifiers		
Road buffer	5	
Building buffer	20	
Railway buffer	5	

Table 3b. Woodland resistance weightings.

Woodland Species Habitat Resistance Ratings		
Habitat Grouping used in Weighting	**Value**	**LEN Habitat Mapping Class**
Ancient woodland with current woodland characteristics	1	Ancient Woodland Inventory Semi-natural Ancient Woodland
Current woodland, apparently natural occurrence	5	Broadleaved woodland
Current woodland, likely plantation occurrence	10	Coniferous woodland Mixed woodland
Current semi-natural unmanaged grassland or wetland habitat	20	Acid grassland Bog and heath Calcareous grassland Fen marsh and swamp Introduced shrubs Saltmarsh Sand dune Wetland and heath
Current low diversity wetland or grassland habitat	30	Neutral grassland Other semi-natural Rough acid grassland Rough calcareous grassland Rough grassland Rough neutral grassland
Improved grasslands and agricultural land	40	Amenity grassland Arable and horticulture Improved grassland Parkland
Urban or suburban land	50	Built-up areas and gardens
Exposed, rocky land	90	Bare ground Coastal above MHW Coastal rock Rock habitats Shingle
Water (Lakes, estuary and saltwater)	999	Flowing water Littoral sediment Outside Study Area Standing and flowing water Standing water Tidal water
Modifiers		
Road buffer	10	
Building buffer	10	
Railway buffer	10	

Table 3c. Wetland and Heath resistance weightings

Wetland and Heath Habitat Resistance Ratings	
Habitat	**Value**
Wetland & Heath	1
Wet grasslands or woodlands	5
Littoral sediments	10
Semi-natural habitats within 250m buffer of wetlands or waterbodies	15
Managed or urban habitats within 250m buffer of wetlands or waterbodies	30
<< Habitats more than 250m from wetlands or waterbodies	50
Exposed or rocky lands	100
Modifiers	
Road buffer	10
Building buffer	20
Railway buffer	10

A lower resistance value suggests a higher quality habitat for the relevant species-group, and that species of this type or association are likely to be found within that habitat-type. A high resistance value suggests that the habitat is dissimilar to the relevant target habitat-type, so such species are unlikely to be found at those sites. Figure 5 illustrates aggregated resistance values for Woodland and Grassland.

Figure 5a. Grassland resistance values

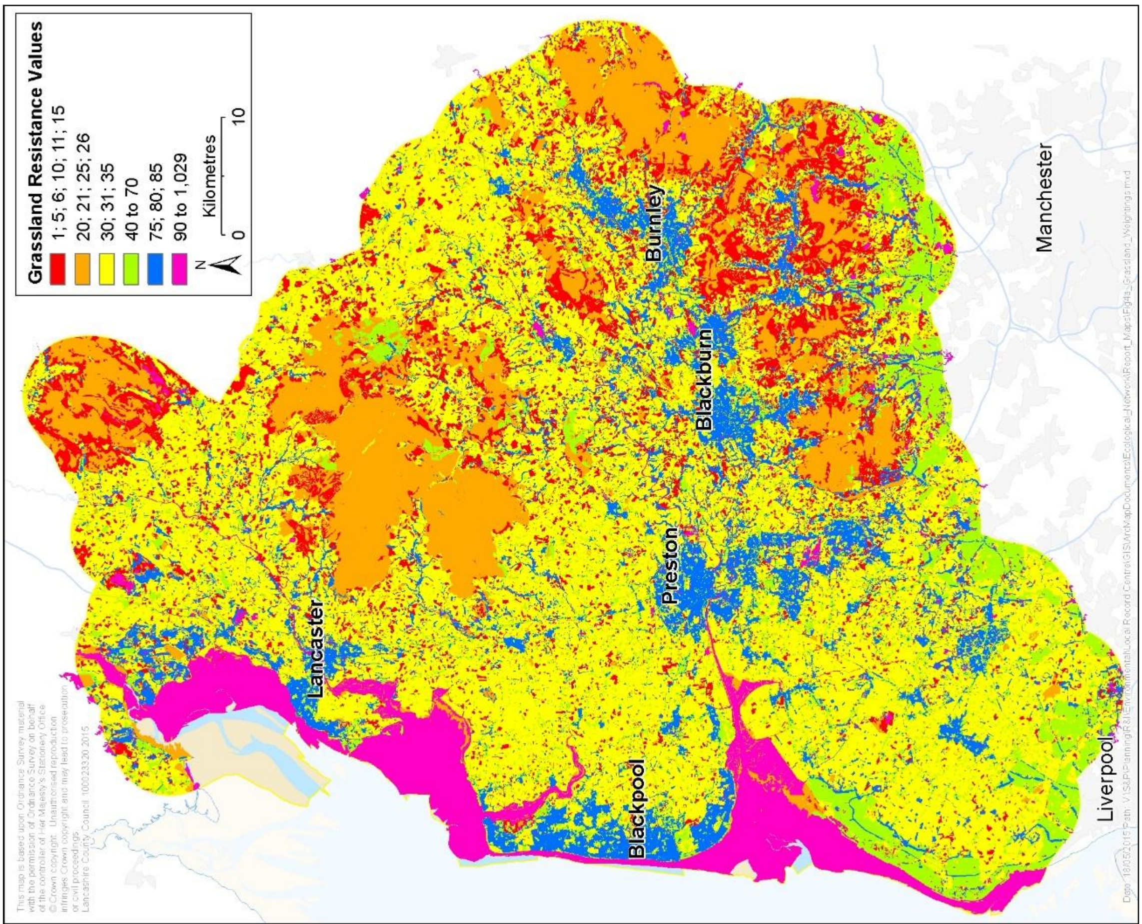
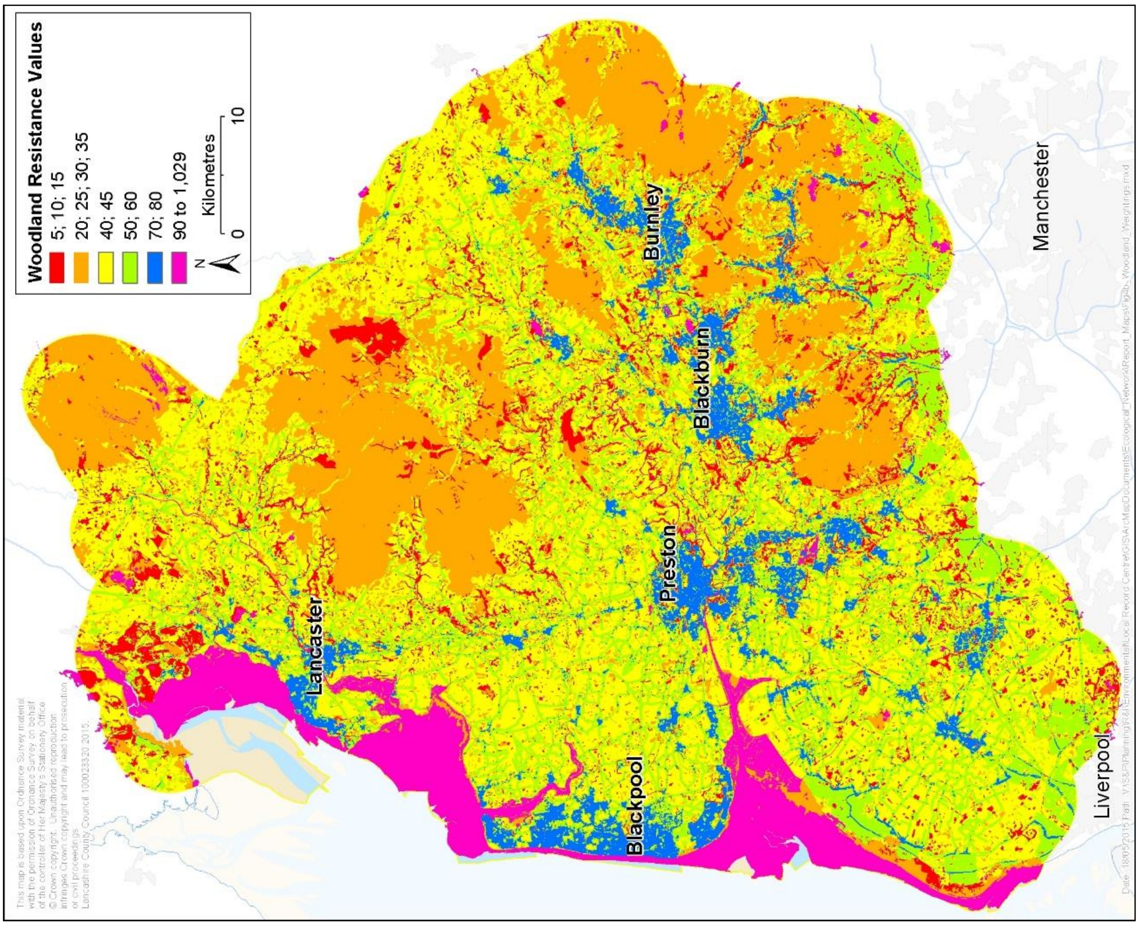


Figure 5b. Woodland resistance values



Resistance values are used to generate least-cost movement paths between sites. The entire study area is divided into equal-sized grid-cells (25x25 m) and each cell is assigned a value based on its predominant habitat. Computer algorithms are used to evaluate all potential paths between two core sites and so identify the unique path that has the lowest cumulative value, *i.e*. the least-cost path.

Least-cost paths are generated for each site, connecting it to adjacent sites within the same habitat-group.

Corridors

Corridors may be identified for the network by identifying the lowest-cost areas. It is possible to designate any amount of habitat from the study area to be included within the corridors. For the purposes of this study, 20% of the study area was assigned to corridor status, with the remaining 80% of habitat being designated as non-corridor.

Corridors may be classified in a number of different ways: by the resistance value of each cell within them; by the number of least-cost paths that run along them; by the value of the shortest least-cost path they contain.

For the purposes of Version 1 of the Lancashire Ecological Network, corridors are classified by the value of the shortest least-cost path they contain. This was achieved by creating Theissen polygons around each vertex along the least-cost paths, and classifying those polygons by the value of the shortest least-cost path passing through them.

Results

Ecological Network Maps

Ecological network maps were created for the three major habitat groups. Each map identifies and classifies the Core Area, Corridors and Stepping Stones, identified for that habitat group.

The mapped network elements are available from LERN as ESRI shapefiles: these are polygonized and attributed to enable the layer to be symbolised in multiple ways as illustrated in the maps comprising Figure 6. Figures 6a-6d do not identify the 0-250m corridors as these are too small to be displayed at the County scale; 6b and 6d only identify the network at the 3km level and do not identify any LEN features in the study area outside the Lancashire County boundary; Figure 6e shows the woodland network at a larger scale where it is appropriate to display the 0-250m corridor class.

Figure 6a. Grassland ecological network mapping

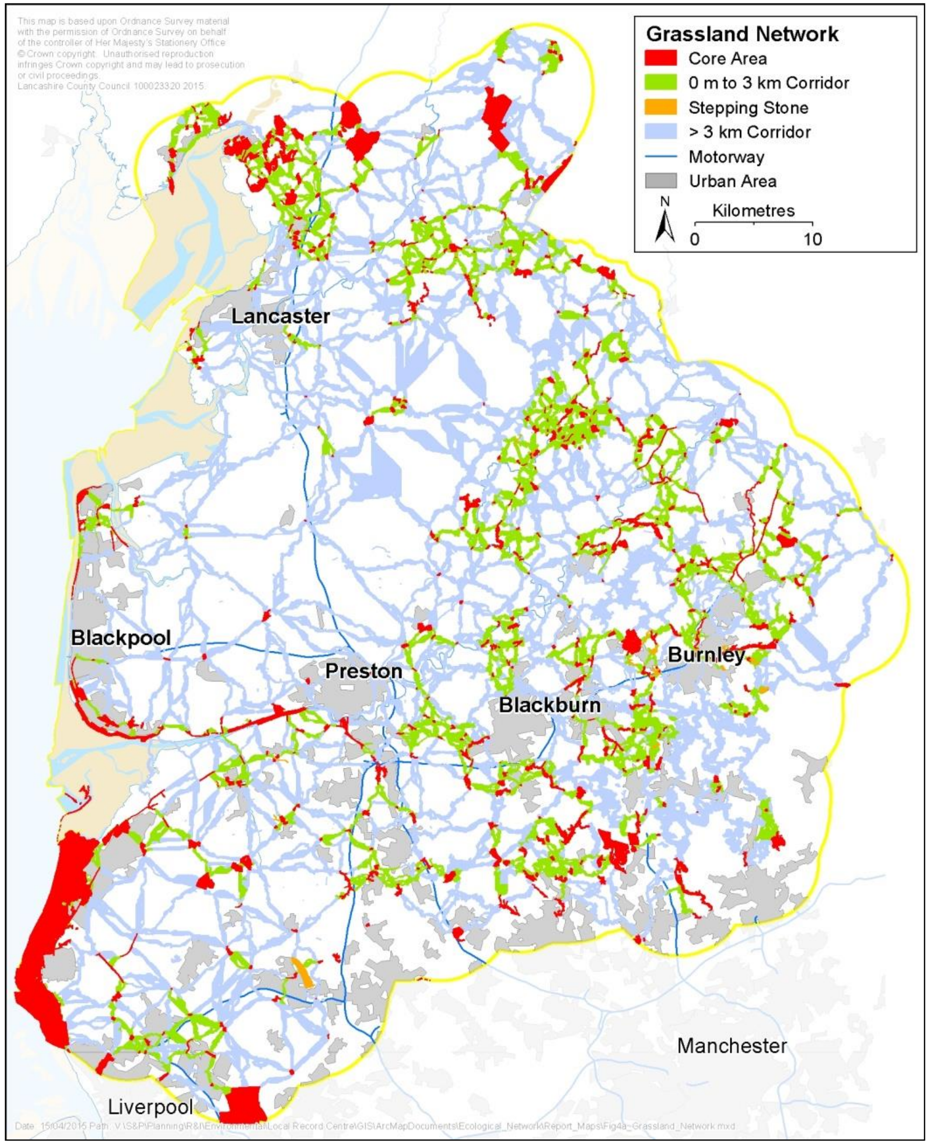


Figure 6b. Grassland ecological network mapping for Lancashire at 3km level

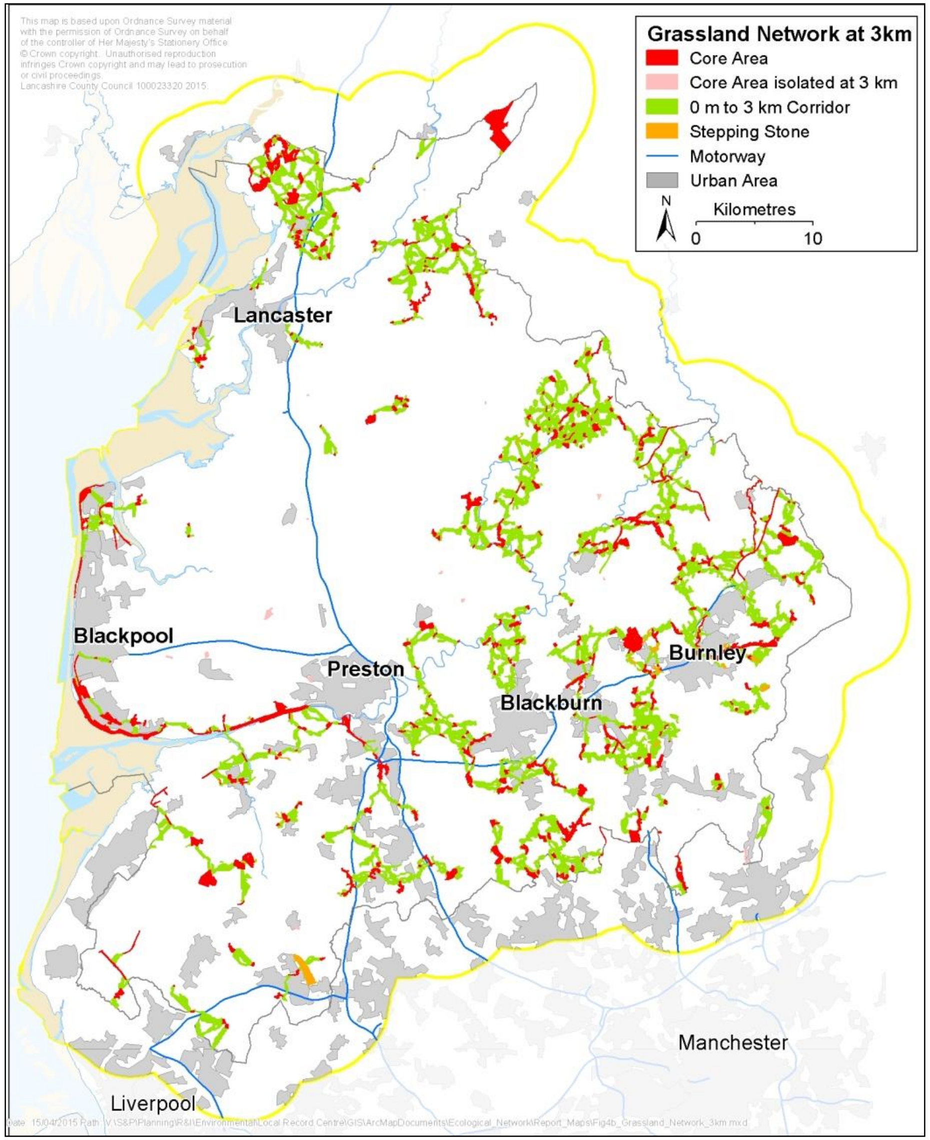


Figure 6c. Woodland ecological network mapping

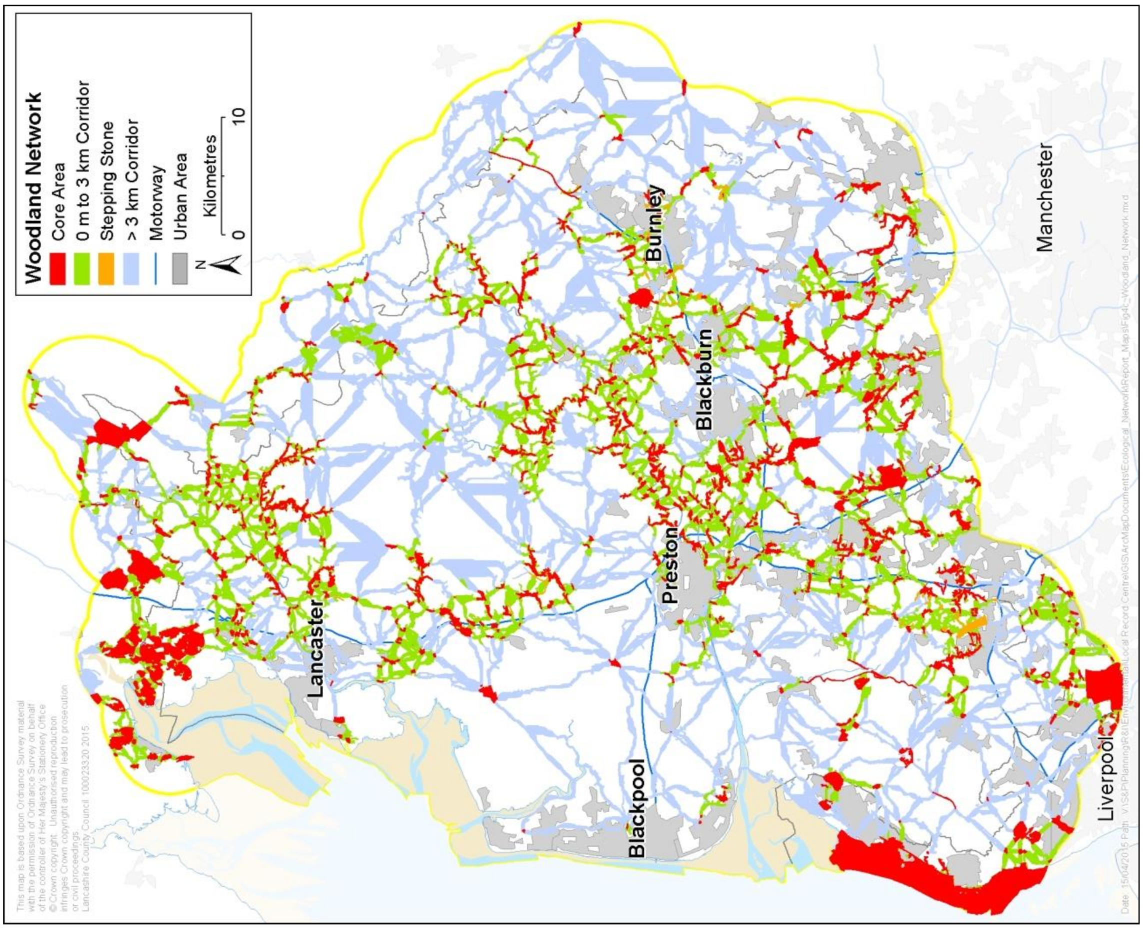
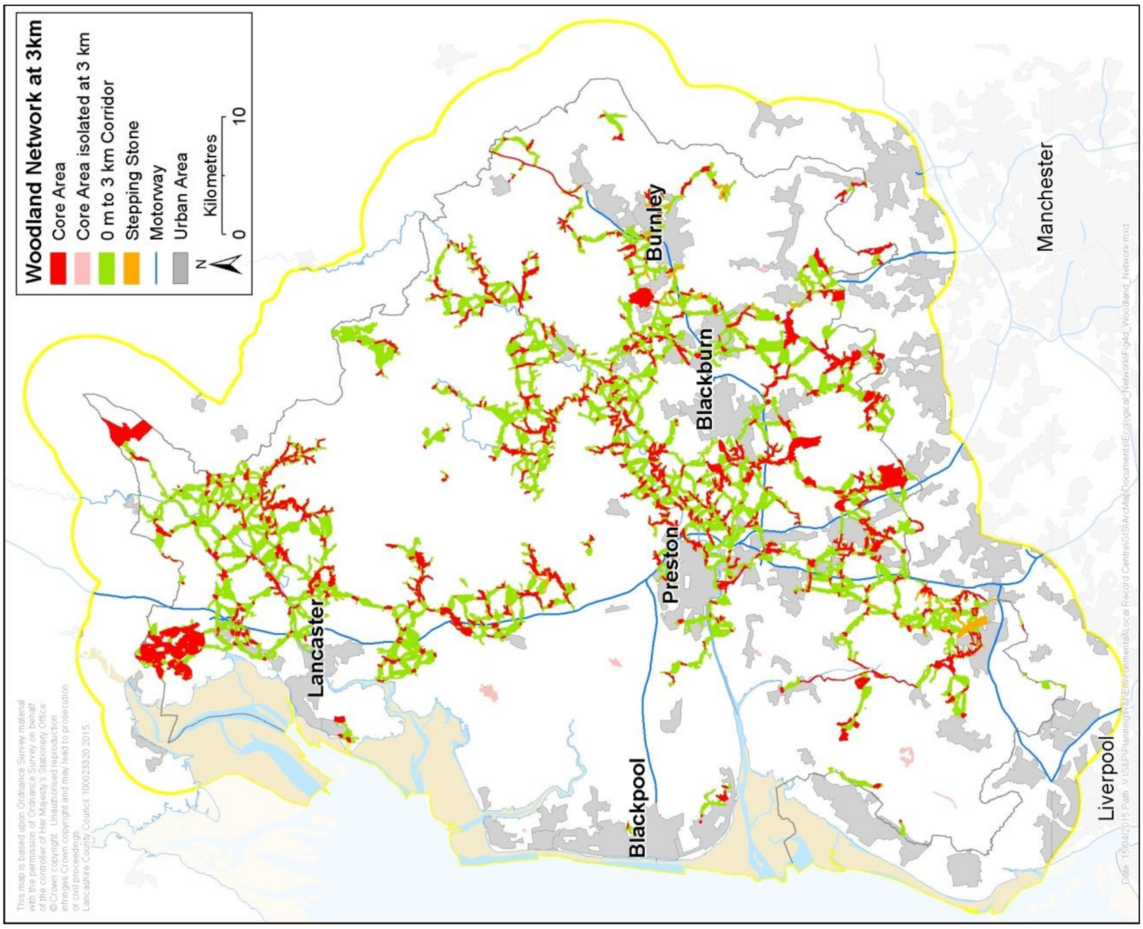


Figure 6d. Woodland ecological network mapping for Lancashire at 3km level



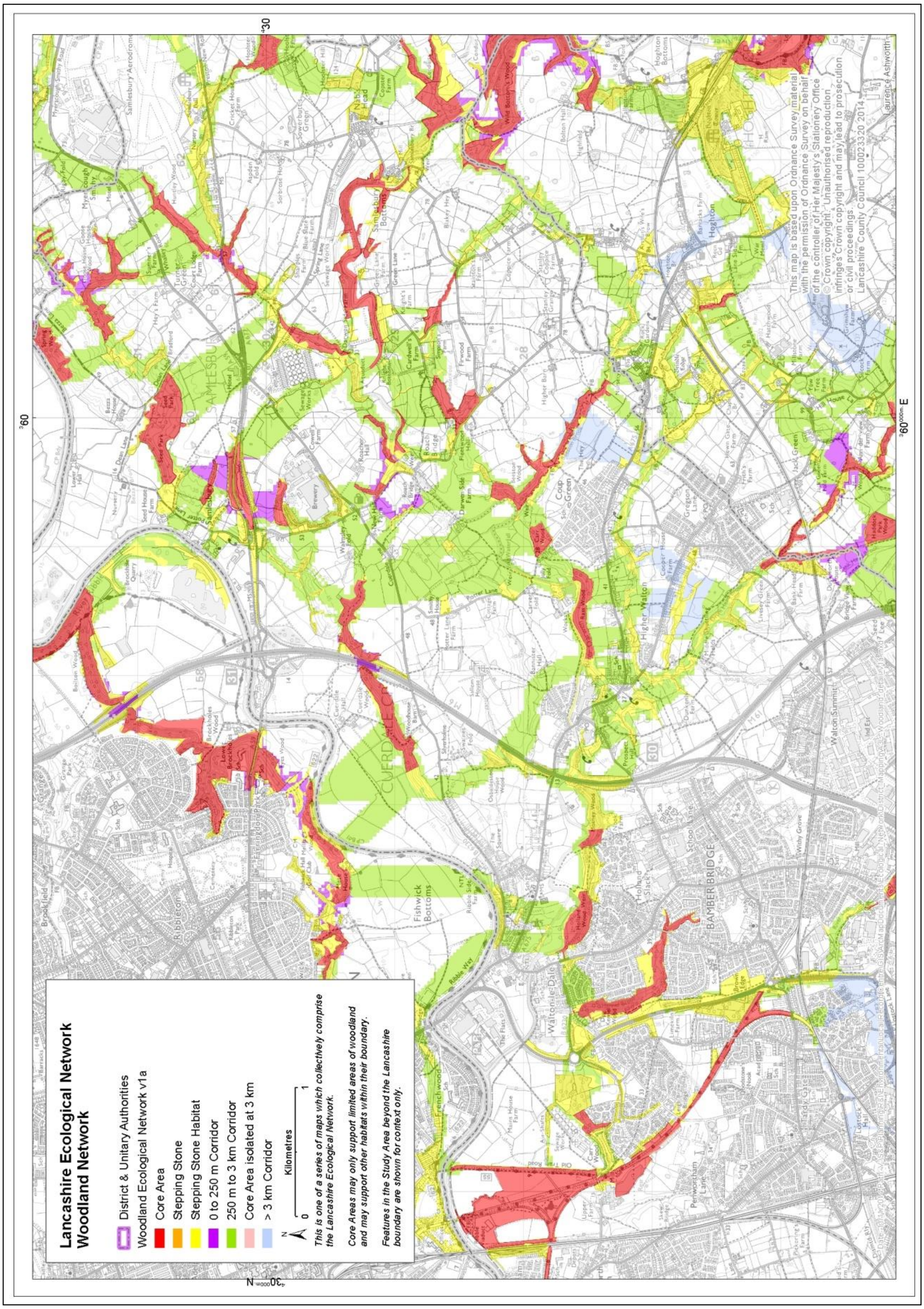


Figure 6e. Detail of woodland ecological network mapping

Characteristics of the Lancashire Ecological Network Core Areas

The comprehensive inventory of sites identified a total of 1,611 sites with some type of conservation designation of at least county importance. In aggregate, these sites cover approximately 26.7% of the whole Study Area, or 18.4% of the terrestrial Study Area and 96% of the intertidal Study Area. The difference is due to a significant proportion of the intertidal component of the Study Area lying within Natura2000 sites.

Looking at individual habitat categories (Table 4), approximately 4% of the terrestrial study area is designated (in whole or part) for protection of woodland, 3% for grassland, and 21% for wetland and heath (note: sites can be designated for the protection of multiple habitat types causing totals to exceed the amount of habitat actually protected).

65% of mapped wetland and heath habitats and 33% of woodland habitats are within the existing core sites but only 4% of grassland habitats are represented (Table 4). However, the grasslands that are under protection are primarily the (species-rich) semi-natural grasslands~~.~~ The high wetland and heath value is explained by the large upland sites. The lower value for grassland is a reflection that the habitat group contains a significant area of semi-improved, species-poor, grassland. Both woodland and grassland also include highly modified types utilised for agricultural and forestry cropping which are not included in these figures.

Table 4 Habitats within Core Areas

Feature	Hectares	% Study Area (% terrestrial)	% Habitat
Study Area (total) Terrestrial Study Area Intertidal Study Area Marine Study Area	487309.4 429111.1 30960.7 27237.6	100 88.1 6.4 5.6	
Grassland total habitat in Study Area	54129.6	11.1	
Grassland Core Areas (may contain habitat other than grassland)	14554.9	3 (3.4)	
Grassland habitat in all Core Areas	9148.9	1.9 (2.1)	16.9
Grassland habitat in Grassland Core Areas	2353.2	0.5 (0.5)	4.3
Wetland & Heath total habitat in Study Area	54109	11.1	
Wetland & Heath Core Areas (may contain habitat other than wetland or heath)	90130.4	18.5 (21)	
Wetland & Heath habitat in all Core Areas	35410.0	7.3 (8.3)	65.4
Wetland & Heath habitat in Wetland & Heath Core Areas	34888.0	7.2 (8.1)	64.5
Woodland primary habitat in Study Area	24480.9	5.4	
Woodland Core Areas (may contain habitat other than woodland)	18059.7	3.7 (4.2)	
Woodland total habitat in all Core Areas	9484.8	1.9 (2.2)	38.7
Woodland habitat in Woodland Core Areas	7995.3	1.6 (1.9)	32.7
Total habitat in Core Areas	120646.6	24.8(19.7) intertidal: 96.3	
Total habitat in Study Areas (N.B. habitat mapping does not cover marine areas)	452534.6		

Each of the habitat networks was defined as covering 20% of the study area. For the woodland and grassland networks this equates to almost 25% of the terrestrial study area.

Table 5a shows the composition of the woodland and grassland networks. Table 5b shows the composition of the same networks at the 3km level.

The majority of the network within the study area comprises the corridors over 3km in length and at the 3km level the largest component is the 250m to 3km corridors. Less than 1% of the area of Core Areas is isolated from the 3km network.

Table 5a. Composition of woodland and grassland networks

Feature	% Grassland Network (All Study Area)	% Woodland Network (All Study Area)	% Grassland Network (Terrestrial Lancashire)	% Woodland Network (Terrestrial Lancashire)
Core Area	13.4	16.6	7.0	11.0
0 to 250 m Corridor	0.3	0.9	0.3	1.0
250 m to 3 km Corridor	19.4	18.8	19.7	21.1
Stepping Stone	0.2	0.3	0.3	0.4
Stepping Stone Habitat	3.6	8.7	4.5	9.2
> 3 km Corridor	62.8	54.3	68.0	57.0
Core Area isolated at 3 km	0.3	0.4	0.1	0.3

Table 5b. Composition of woodland and grassland 3km networks

Feature	% 3km Grassland Network (All Study Area)	% 3km Woodland Network (All Study Area)	% 3km Grassland Network (Terrestrial Lancashire)	% 3km Woodland Network (Terrestrial Lancashire)
Core Area	35.9	36.2	21.9	25.6
0 to 250 m Corridor	0.9	2.1	1.0	2.4
250 m to 3 km Corridor	52.2	41.2	61.6	49.0
Core Area isolated at 3 km	0.7	0.8	0.4	0.6
Stepping Stone	0.6	0.6	1.0	1.0
Stepping Stone Habitat	9.6	19.0	14.1	21.4

Figure 7a. Composition of 3km grassland network for the Study Area.

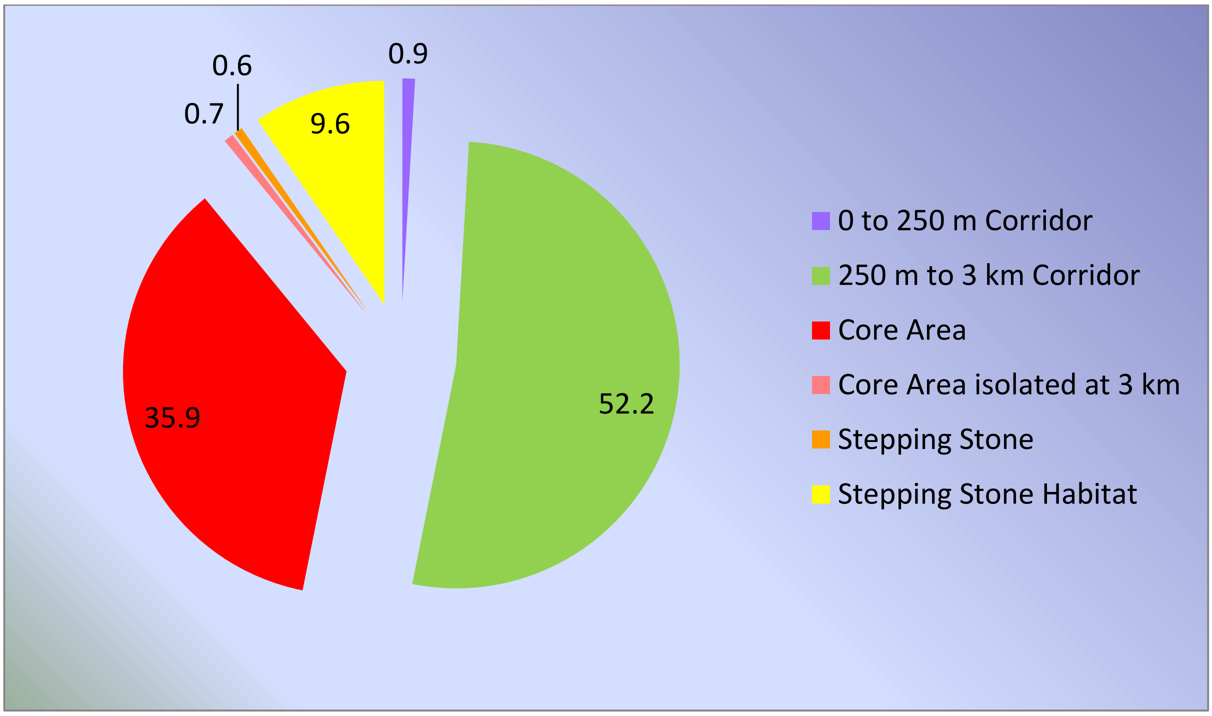
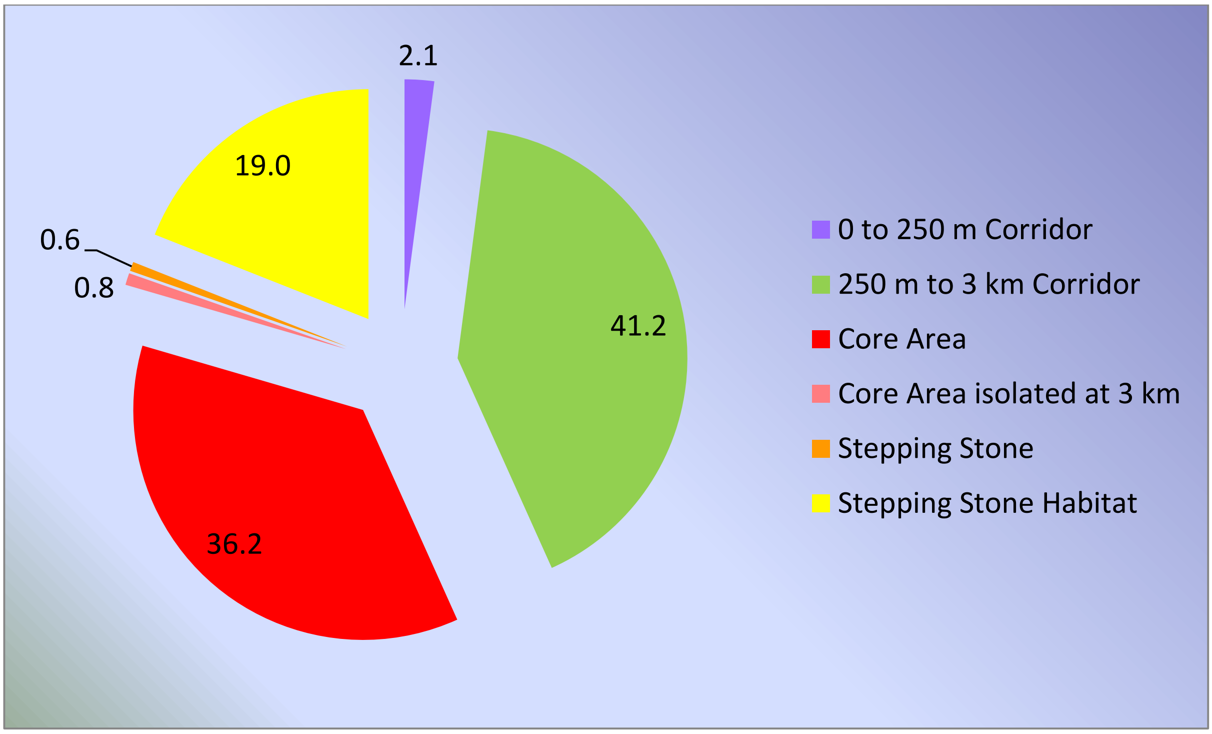


Figure 7b. Composition of 3km woodland network for the Study Area.



Habitat

By mapping the habitat types within the existing protected area network we can begin to understand how the habitats are distributed and afforded protection.

Figure 8. Habitat types within Core Areas

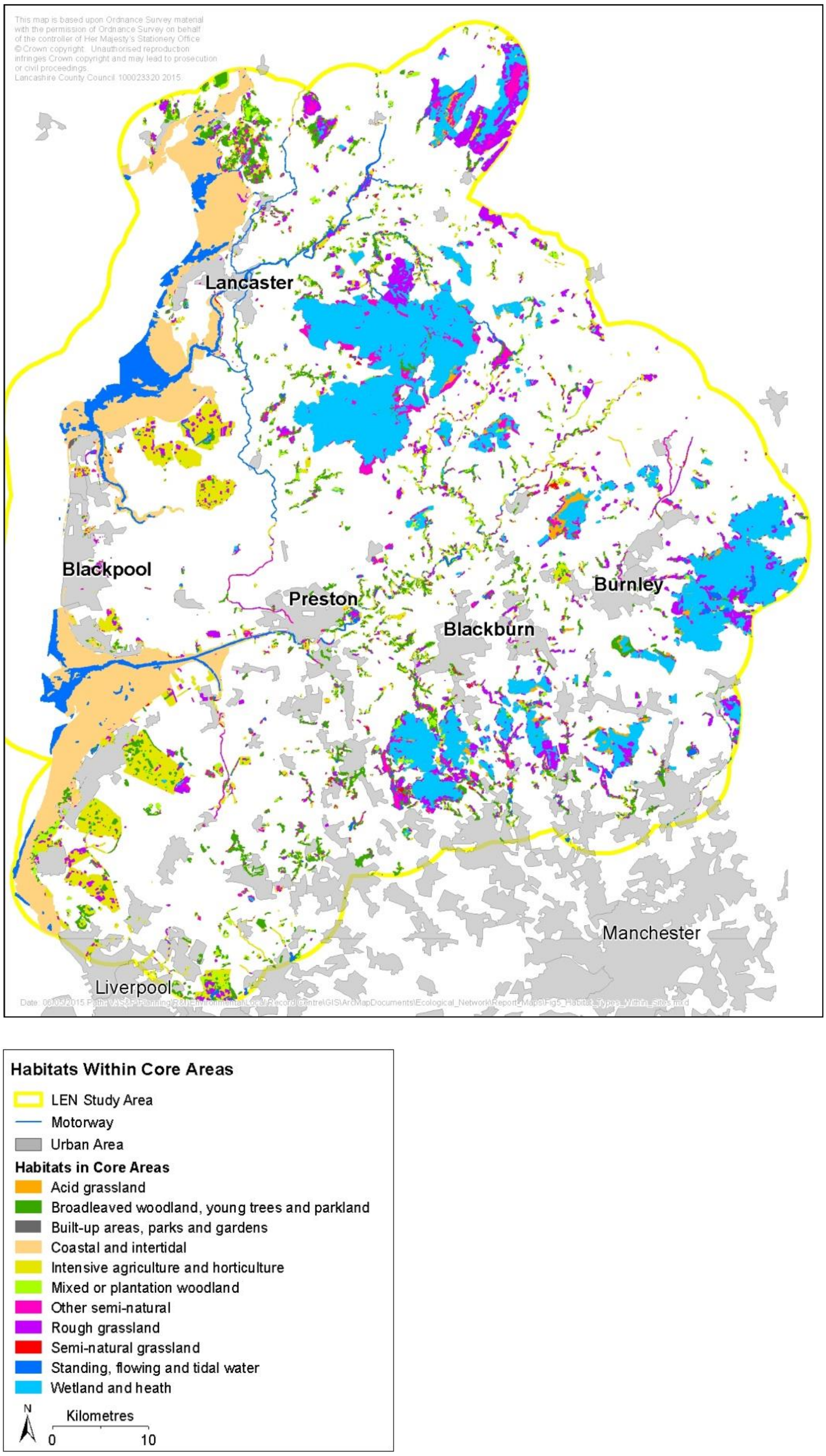
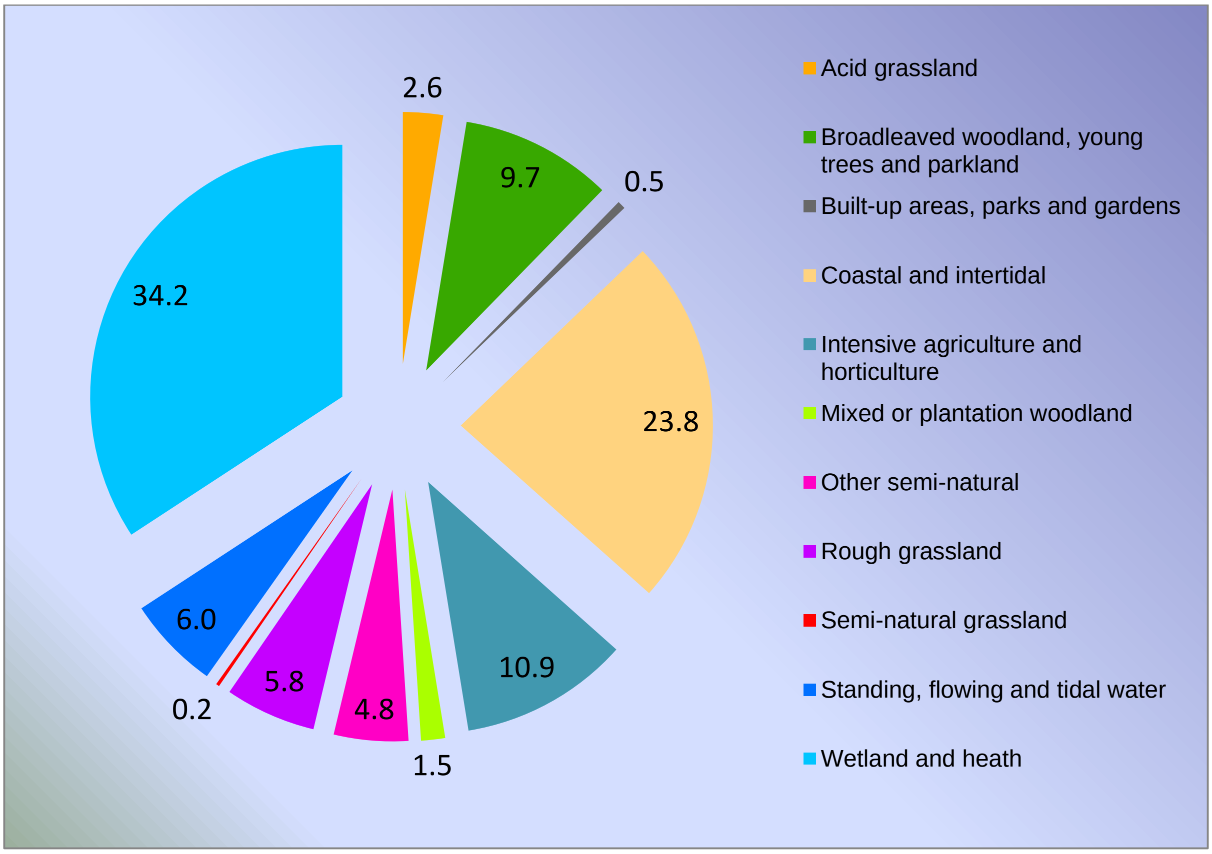


Figure 9. Core Area habitat composition



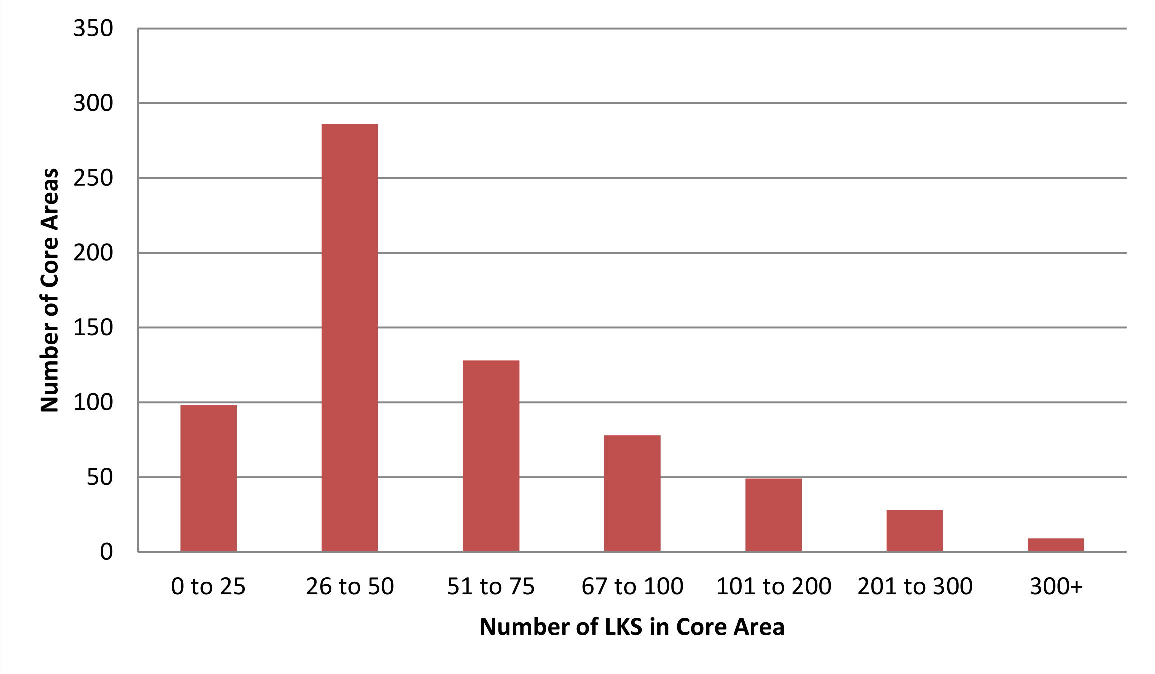
Species

We were also able to assess the number of Lancashire Key Species (LKS) observations that have occurred on or near core sites within Lancashire (the 5km buffer was excluded from this analysis). The Lancashire Key Species record set analysed included:

- The Conservation of Habitats and Species Regulations 2010;
- The Wildlife and Countryside Act 1981 (as amended);
- The Natural Environment and Rural Communities (NERC) Act 2006 - Habitats and Species of Principal Importance in England;
- Lancashire BAP Species and Lancashire BAP Long List Species.

LKS observations taken from the LERN database were compared to core site locations to determine which species occurred in which sites. A total of 676 core sites were evaluated and the number of species on each site ranged from 1 to 382 species (Figure 10). There were between 1 and 22,904 individual observations of individual species per site. The distribution of species throughout the ecological network is not even, with some sites containing relatively large numbers of individual species and other sites providing habitat for a relatively small number. The following chart depicts the number of species known to occur on or near core sites.

Figure 10. Number of species per Core Area



Least-cost Paths and Species Dispersal

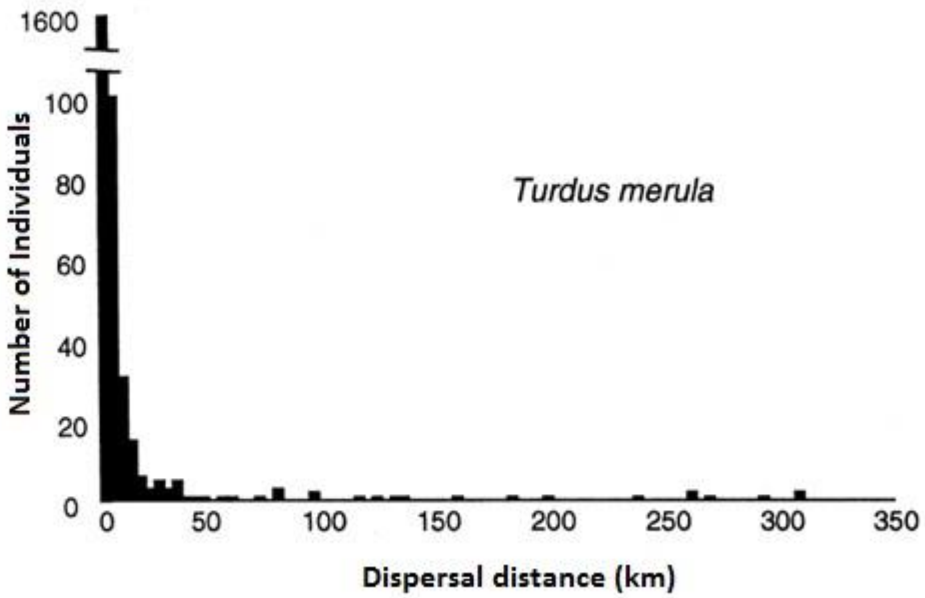
In general, shorter routes, and routes through higher quality habitat, are preferable for habitat connectivity as the network theory suggests that species are more likely to successfully move between sites in these circumstances.

Least-cost path lengths can be compared to the shortest straight-line route between two points. Routes that are longer than the minimum suggest either an ‘attraction’ to higher quality habitat or an ‘avoidance’ of low quality habitat.

Long paths between sites may represent paths that are only accessible to some species – and, therefore, present a lower likelihood of successful movement overall.

Habitat selection is the behavioural process that species use to choose resources and habitats. These choices happen at a variety of scales and it is assumed that habitat selection is motivated by a drive to maximise individual fitness. How individuals and populations of a given species perceive and interact with an ecological network is dependent on their abilities to disperse and to use habitat(s) outside of core sites for movement, feeding and refuge. Studies on dispersal distances have repeatedly found that, regardless of the maximum dispersal capability of a given species, the frequency of dispersal decreases with increasing distance. Figure 11 shows recorded dispersal distances for Common Blackbird (*Turdus merula*) and illustrates a typical pattern for species dispersal.

Figure 11. Frequency of dispersal decreases with increasing distance in Common Blackbird. (Taken from Paridis *et al*. 1998).



Although individual blackbirds are capable of dispersing more than 300 km, the vast majority are found less than 5 km from their initial capture site. A review of 75 terrestrial bird species (Paridis *et al*. 1998) found that three had average breeding dispersal distances of 800 metres or less (Eurasian Nuthatch, Yellowhammer, and European Skylark). However, each of these had higher natal dispersal. The species with the shortest average breeding and natal dispersal was the House Sparrow with 1.9 and 1.7 km respectively. This result most likely reflects the capacity of House Sparrows to adapt to a wide range of habitats rather than an intrinsic limitation to this species' dispersal ability. The longest average dispersal distances are 44.5 and 47.0 km for the Black-headed Gull.

This range of dispersal capabilities illustrates that different species are likely to perceive habitats differently, with some species able to cover great distances easily, while for others a relatively short distance may create a barrier to movement. For this reason we have evaluated ecological connections for a range of potential dispersal capabilities. This allows us to illustrate how the Lancashire Ecological Network might function for relatively dispersal-limited species as well as to evaluate how the network might operate without dispersal limitations. A recent study in Somerset (Burrows *et al* 2011) identified lower bounds for dispersal of 800 metres for woodland species and 700 metres for agriculturally unimproved grasslands. Semlitsch and Bodie (2003) found that the mean maximum distance that generic herpetofauna (amphibians & reptiles) extend into terrestrial habitat is approximately 300 metres. In its guidance on Great Crested Newt mitigation, Natural England refers to movements of 1.3 km from breeding sites, but the vast majority of these newts will inhabit an area much closer to the breeding pond. The local environment has a significant bearing on dispersal. Several studies have been conducted which reveal a great deal of variation, but Great Crested Newts commonly move between ponds that are within around 250m of each other.

Research reported from Scotland (Xavier Lambin 2012) using mark-recapture, indicates that, in an existing fragmented landscape, young Water Voles can travel large distances from their natal areas. Water Voles typically have a home range of a few hundred square metres. They were recorded moving two to three kilometres, with a few moving up to 15 kilometres between natal areas and the sites of their first reproduction.

Jenkins (1980) followed the movements of one young male European Otter in northeast Scotland. Up to the age of around eight months the animal's activities were confined to the loch on which it was raised. Over the succeeding months it extended its range along the River Dee. By the age of one year it had been recorded along 68 km of the river, travelling distances of more than 20 km in a single night. Melquist & Hornocker (1983) studied the related North American River Otter. Young otters dispersed at 12–13 months of age. A male travelled 104 km in 30 days and established a home range 32 km from its natal area. A female travelled 195 km in 50 days but then settled into a range adjacent to its mother's and partly overlapping it. In contrast, two males had not dispersed from the natal range when contact was lost at 16 and 25 months old respectively.

What this illustrates is that, even amongst individuals of the same species, dispersal distances can vary greatly. There is also a tendency for individuals (especially males) of many animal species to move greater distances in their adolescent life stage, then settle down to a more defined range when mature and breeding.

Ecological Corridors

The Lancashire Ecological Network identifies 20% of the study area as corridors; these are classified by the value of the shortest least-cost path they contain. Corridors may be classified in a number of other ways to suite different scenarios, for example by the:

- resistance value of each cell within them;
- number of least-cost paths that run along them;
- value of the shortest least-cost path they contain;
- area of semi-natural habitat;
- presence of significant barriers;
- coincidence with other social, economic or environmental features.

The corridors were used to select habitat parcels from the habitats layer (Table 4). These habitats are assumed to form stepping stones along the corridor. Habitat quality and presence of barriers can also be evaluated for each corridor:

- High quality habitat may indicate opportunities for continued protection and preservation

- Low quality habitat may indicate opportunities for habitat creation or restoration.
- Barriers may require case-by-case evaluation to understand how wildlife is being impacted by the barrier, and appropriate management measures to facilitate species movement.

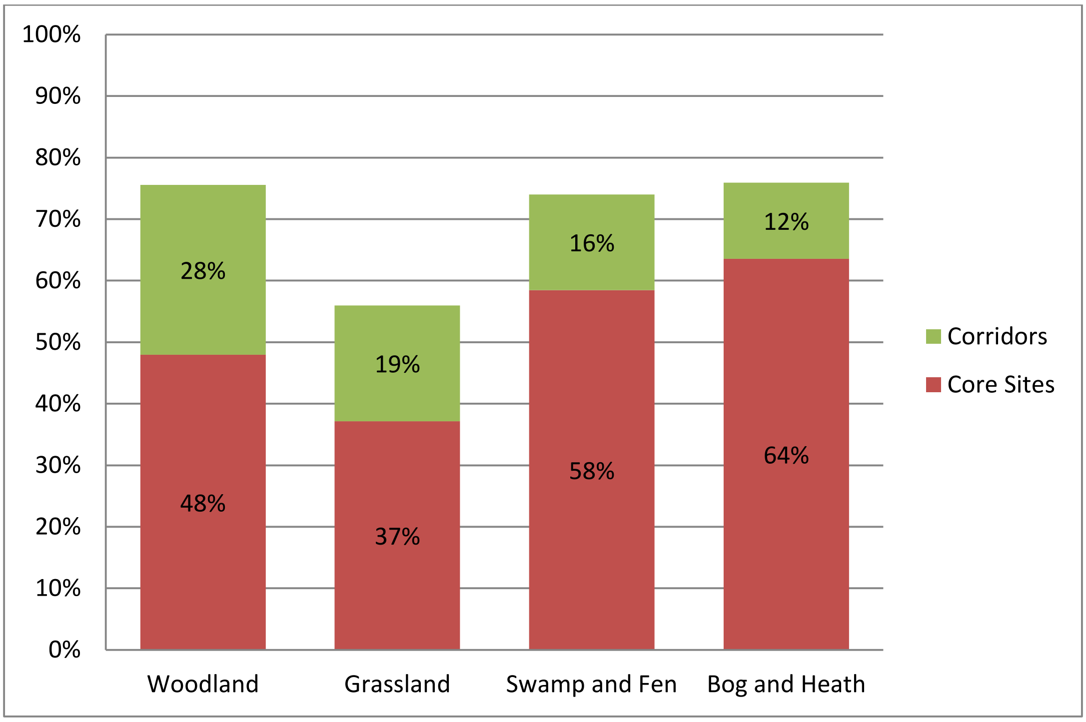
Ecological Network

Adding corridors to the core sites should increase the proportion of species-observations that are contained within the ecological network.

Figure 12 below, illustrates the proportion of Lancashire Key Species observations recorded in the LERN database. This database is believed to have a bias (at levels of greater recording precision) toward observations of species within Core Areas as field survey efforts tend to have been greater in these areas. Conversely, field survey efforts have been greater in these areas because they are the locations in which significant species assemblages are found. However, no systematic sampling has taken place throughout the study area at a suitable resolution (*e.g.* 100m or greater). Figure 12 illustrates the incremental value that the Core Areas and corridors provide in addressing the requirement in the NPPF for Local Planning Authorities to protect and secure the recovery of Priority Species.

For most networks, combining the Core Areas and corridors results in the proportion of known priority species observations lying within the network exceeding 70%. As stated previously in this report, a smaller proportion of grasslands is captured within the protected areas than is the case for other habitat types. This probably contributes to the relatively low proportion of grassland species observations captured by existing protected areas. However, it is likely that actual species distributions are not as highly concentrated in Core Areas as these analyses would suggest, given that precise species recording effort (*i.e.* >100m precision) and the capture of records digitally is skewed towards existing protected areas.

Figure 12. Locations of Lancashire Key Species.



Stepping Stones

Stepping Stones have been defined based on:

1. the location of priority habitat outside Core Areas (and within or intersecting the corridors); and
2. the location of wildlife sites identified as being of importance at the local level (sub-county).

Sub county-level wildlife sites include: important road verges, and district level wildlife sites identified in: West Lancashire, Burnley, Pendle and Rossendale. As with Core Areas, these are classified by the habitat group network(s) to which they contribute.

Priority habitat in local sites is assumed to be of demonstrable environmental significance. That identified within the habitats layer, but outside a local site, will be of uncertain quality due to the limitations of the habitats dataset (see Table 1). A distinction has therefore been made, on the Lancashire Ecological Network maps, between 'Stepping Stones' and 'Stepping Stone Habitats'

Table 6 identifies the components of the habitats layer which comprise the Stepping Stone Habitats for each network.

Table 6. Relationship between habitats layer and Stepping Stone Habitats

Network	LEN Habitat Mapping Class	Count of Polygons	Hectares
Grassland Stepping Stone Habitat	Calcareous grassland	105	60.9
Grassland Stepping Stone Habitat	Neutral grassland	1931	388.2
Grassland Stepping Stone Habitat	Rough calcareous grassland	107	128.7
Grassland Stepping Stone Habitat	Rough neutral grassland	8866	7425.6
Grassland Stepping Stone Habitat	Sand dune	404	668.1
Woodland Stepping Stone Habitat	Broadleaved woodland	79250	16517.9
Woodland Stepping Stone Habitat	Mixed woodland	7230	1379.9
Woodland Stepping Stone Habitat	Scrub or young trees	8222	2601.1
Wetland and heath Stepping Stone Habitat	Bog and heath	6560	14265.2
Wetland and heath Stepping Stone Habitat	Fen marsh and swamp	6413	5023.8
Wetland and heath Stepping Stone Habitat	Wetland and heath	241	1061.4

Measuring Ecological Connectivity

Ecological connectivity between habitat patches is a concept that is strongly supported by ecological theory, and empirical study, as beneficial for the movement of genes, individuals, populations and species. Furthermore, it has benefits over varying time periods:

- short time-periods – *e.g.*, facilitating successful dispersal to empty habitat patches;
- intermediate time scales – supporting migration and persistence of meta-populations; and
- large time scales – movements of species ranges in response to climate change

(Minor and Urban 2008).

Effectively measuring and describing connectivity is less straightforward. However, graph theory unifies many aspects of habitat connectivity into measures that are based on research on computer and social networks. Using this approach to evaluate ecological connectivity, habitat patches are considered "nodes" while the connections between them are "edges."

In considering the Lancashire Ecological Network, we chose to analyse a range of potential movement distances to reflect the varying capabilities of species present within the network. Relevant measures of connectivity are:

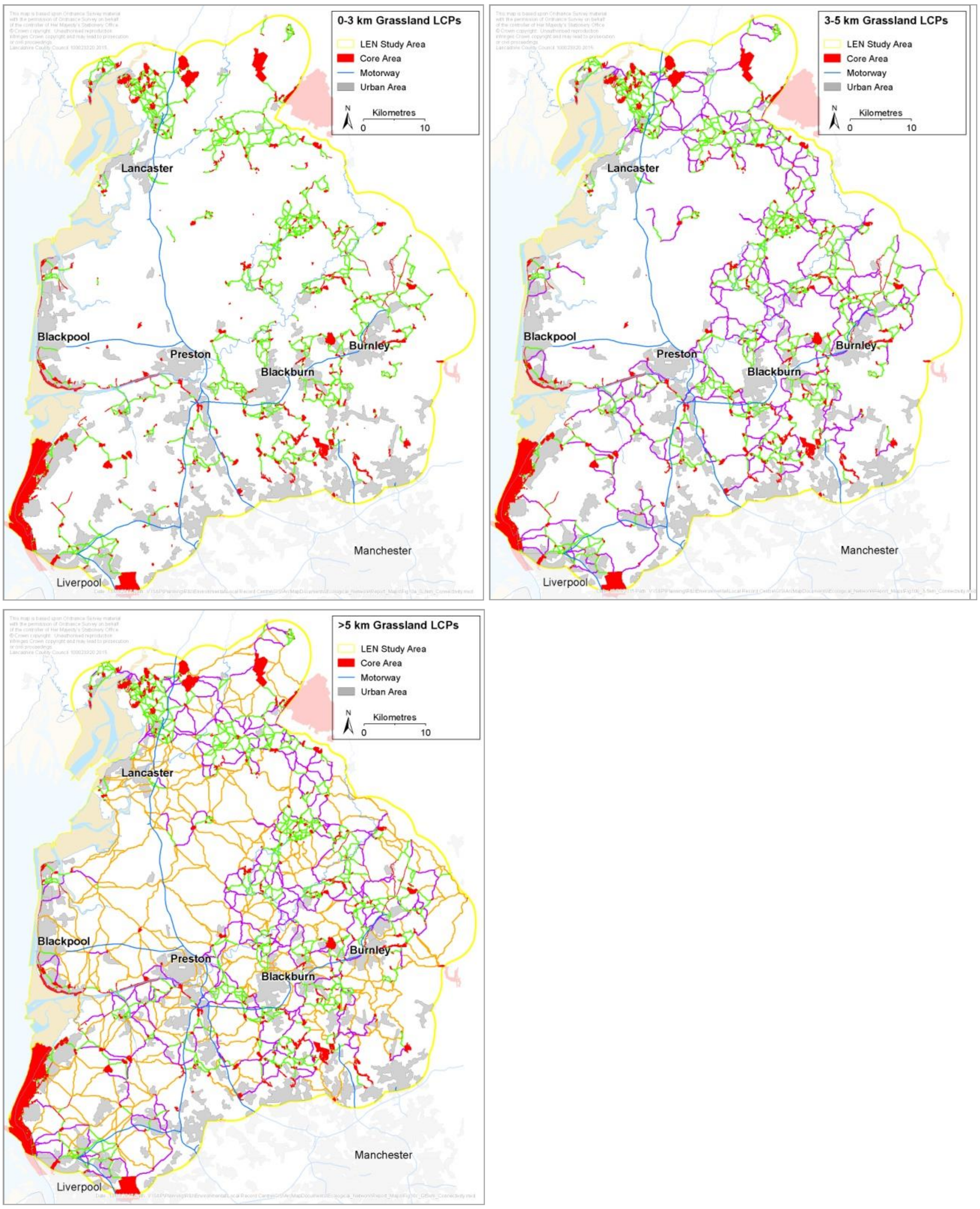
I. the number of ecological networks in a study area;
II. the number of habitat 'patches' contained in each of those networks; and
III. the total area of 'patches' within a network.

For example, as we increase the potential Wetland and Heath least-cost path length from 0 metres, first to 250 metres; then to 3 kilometres; then to 5 kilometres; and, ultimately, to no restrictions, we note that the landscape, predictably, becomes increasingly connected, going from over 200, to 24, to 5 and, ultimately, to 1 network respectively (figure 13). The opposite is true about the number of paths connecting sites. Those increase as the potential length of least-cost paths increases (Table 7). This demonstrates how species with relatively short dispersal-capabilities will perceive even a relatively dense set of habitat-patches as being fragmented; whereas species with more extensive capabilities would perceive the same habitats as being connected.

Table 7. Relationship between least-cost path length and number the number of least-cost paths connecting Core Areas

LCP Length	Wetland and Heath (cumulative total)	Grassland (cumulative total)	Woodland (cumulative total)
0 to 0.25 Km (0 to 0.25 Km)	157 (157)	261 (261)	427 (427)
0.25 to 3 Km (0 to 3 Km)	415 (572)	794 (1055)	924 (1351)
3 to 5 Km (0 to 5 Km)	193 (765)	314 (1369)	249 (1600)
5 + Km (0 to 5+ Km)	245 (1010)	391 (1760)	229 (1829)

Figure 13. Ecological connections between grassland sites at various corridor lengths.



For the purposes of developing a functional ecological network for Lancashire we have chosen to focus our attention on corridors of 3 kilometres or less as the corridors that are most likely to be contributing to movement of individuals and species (Figure 14). This distance represents an intermediate dispersal capability and is proposed here as an interim standard for evaluating overall network condition and connectivity. This measure can be adjusted upwards or downwards for individual habitat types or for all habitat types as future research may indicate to be appropriate.

Information on corridors greater than 3km in length is potentially useful and is included within the published GIS layers. It can, for example, be used to identify and target conservation activities at areas which could be enhanced to connect 3km networks that are currently isolated from each other.

At the 3km level, the networks (where two or more sites are joined by a corridor) for each of the three habitat groupings are fragmented with Woodland having the fewest (better connected) networks, and Wetland and Heath the most (least well connected) (Table 8). 3km networks for woodland and grassland are illustrated in Figure 14.

Table 8. Habitat networks at the 3km level

Habitat	**Number of Networks at 3km in Study Area** (number wholly or partially within Lancashire)
Grassland	33 (27)
Wetland and Heath	Not finally determined for draft
Woodland	19 (14)

Figure 14a. Contiguous grassland networks comprising corridors of up to 3km

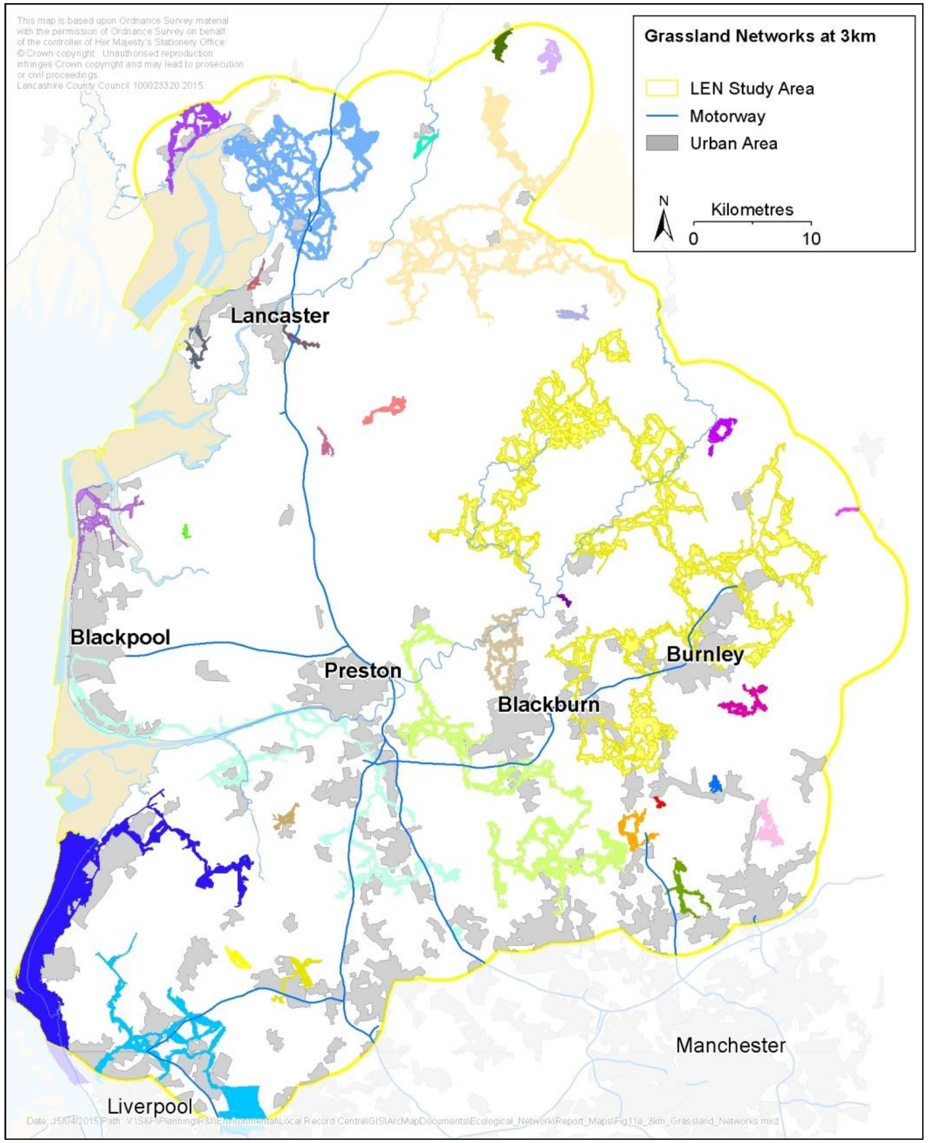
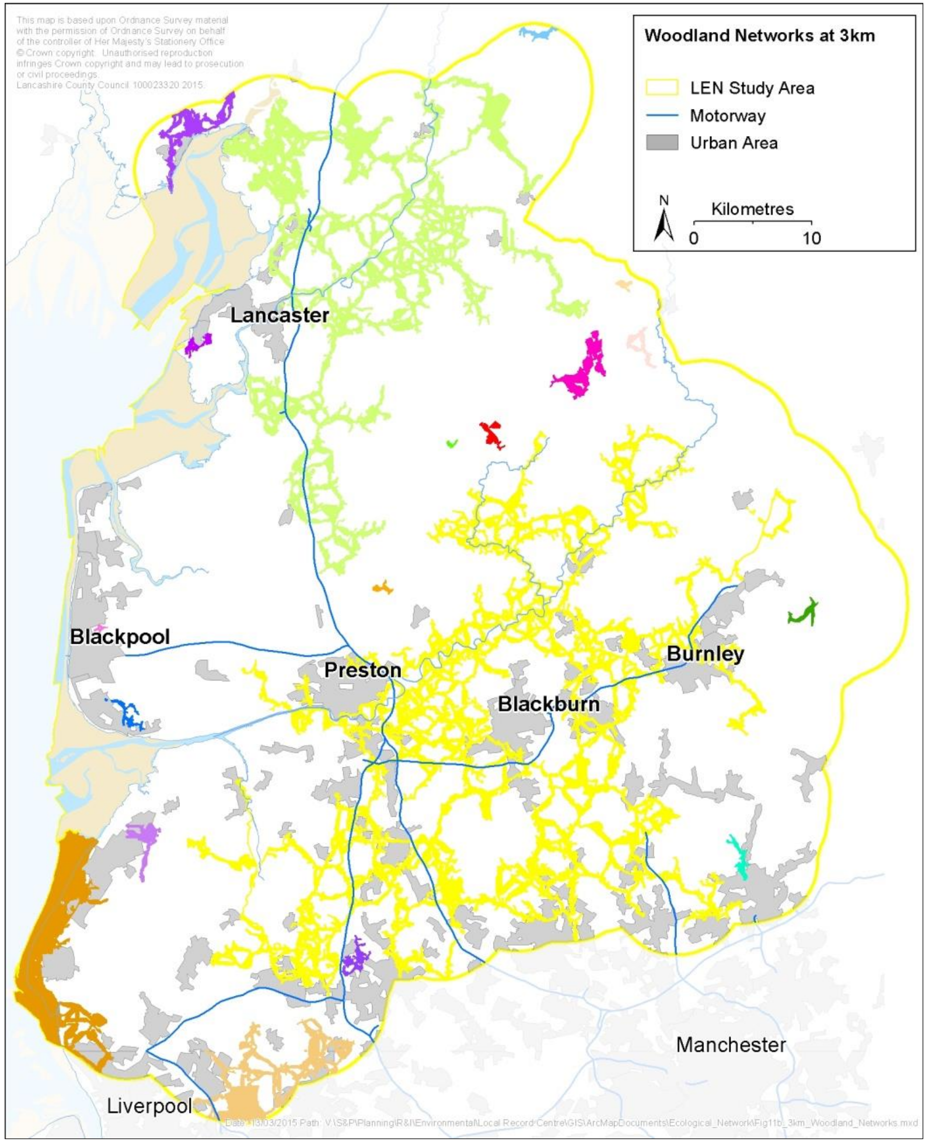


Figure 14b. Contiguous woodland Networks comprising corridors of up to 3km



Review, Monitoring and Development

The work so far undertaken, and presented here, is only the first step in identifying a county-wide ecological network for Lancashire. Data and other resource limitations have constrained the analysis and outputs, as described through this report. Given further resources we have identified a series of options for further work including:

1. Addressing data limitations that prevented us from completing some analyses that have been undertaken elsewhere, or could enhance the ecological network model presented here. This would include:

    i. Continuing collection and collation of species observation data throughout LERN, in particular, it would be valuable to improve record precision and determine the level and significance of any statistical bias in survey effort within and outside core areas.

    ii. Collecting digital data describing the location and condition of hedgerows.

    iii. Improving spatial data regarding areas under conservation management (e,g,. areas receiving subsidies to support conservation management and areas where positive interventions have been enacted);

    iv. Improving and refining habitat data, *e.g.* by re-evaluating habitat condition within the ecological network as new surveys of land-use and habitat data become available.

    v. Identifying and prioritising areas within or adjacent to the existing network that are priorities for habitat restoration or may function as buffers or “set-backs”.

    vi. Investigating options and mechanisms to integrate other datasets with the existing network to enhance the value as a targeting tool. For example, the extent of peat-based soils will inform the identification of areas potentially suitable for the restoration of wetland habitats. Other datasets that could be integrated include: steeper slopes (woodland and grassland), wind-blown sand (dunes and coastal grassland), marl (ponds), surface limestone (grassland and rock habitats) and alluvial deposits (wetlands after mineral extraction).

    vii. Identifying opportunities for reducing the barrier-effects of transport infrastructure. Mapping of road-kill and its analysis in relation to the identified networks to identify existing, significant wildlife crossing locations on the transport network and so identifying the potential for green overpasses, underpasses, culverts and other mechanisms for facilitating wildlife crossings and reducing mortality.

2. Improving understanding of the functionality of the corridors depicted in this study and predicting the habitats and routes that species are likely to use. Further work could:

   i. Track species movements and dispersal using capture-recapture studies or tracking equipment.

   ii. Integrate the results within the plans and strategies of local government and agencies operating within Lancashire to prioritize habitat protection and enhancement towards core areas and corridors, relative to other areas in Lancashire County.

3. Integrate the Lancashire Ecological Network outputs with other area- or habitat-based landscape-scale investigations, such as those undertaken in the Morecambe Bay Nature Improvement Area and River Ribble catchment.

4. Investigate cross-boundary links with ecological networks developed for neighbouring areas. This may include the value of areas within Lancashire that have a significant role in networks at the national and international scale.

5. Investigating other scales: this network has been developed at the county level to provide a context to enable individual planning authorities to meet the requirements of NPPF. It may be appropriate to further refine or develop the network to a district or other subsidiary level according to the needs and requirements of relevant users. For example, the current scale of mapping may require enhancement in an urban context.

6. Investigate the relative importance of core areas to the network as a whole.
   i. One relatively simple measure of a given site's importance in an ecological network is its centrality, or how many sites connect to it. Freeman (1978) formalized a simple measure of centrality, 'degree', which measures the number of connections to a given 'node' (also known as a 'habitat patch' or 'site').

   ii. There are, at least, three contexts for evaluating the relationship of core areas to the ecological network. Cores may:
      - be large or productive - in which case they are likely to produce surplus species-offspring that could disperse across the landscape (*e.g.*, source/sink meta-populations as described by Pulliam (1988));
      - be well-connected to other sites and therefore provide intermediate connections or *refugia* between core sites, even if these are not particularly large (*e.g.* dispersal along habitat fragments); and

- provide a bridge or stepping-stone connecting otherwise disconnected elements of the landscape (*e.g.* the 'spreading of risk' meta-population model (den Boer 1968, Levins 1969)).

7. Investigate species/site relationships:
   i. Area Features
      - Total area
      - Boundary characteristics

      Sites that are connected to a network that includes larger sites are at less risk of local extinction than sites not connected to a network. (In general, small sites are unlikely to be self-sustaining in isolation and large sites are likely to contribute to overall network fitness.)

   ii. Investigate the relative importance of habitat quality and presence of barriers for each corridor:
      - High quality habitat may indicate opportunities for continued protection and preservation
      - Low quality habitat may indicate opportunities for habitat creation or restoration
      - Barriers may require case-by-case evaluation to understand how wildlife is being impacted by the barrier, and appropriate management measures to facilitate species movement.

   iii. Investigate options to quantify the contribution that a Stepping Stone makes to the ecological network through its size and position relative to other network components: larger sites are considered potentially more valuable than smaller ones, and those within or adjacent to Corridors more valuable than those at a distance.

8. Investigate the relationship between the identified ecological networks and records of associated Priority Species. Assess the role of the network as a mechanism to address the requirements of NPPF for local authorities to seek the protection and recovery of priority species populations.

9. Investigate the relationship with other models for identifying the optimum locations for positive interventions to enhance connectivity and climate-change resilience; *e.g.* '*Condatis*' (www.condatis.org.uk), developed at Liverpool University. Such measures could help address the requirement in the NPPF to plan positively for the *'creation, protection, enhancement and management of networks of biodiversity.*

10. Consider expanding the network to cover:

    i. Rivers, Streams and Canals. Due to their linear and continuous nature, rivers and streams are assumed to form a natural network with the shorelines constraining the network. Rivers and streams should, however, be a focus of further investigation for the identification and correction of water quality issues, barriers (weirs) and other hard engineering (culverting, channelisation *etc*).
    ii. Lakes and Ponds;
    iii. Coastal Habitats;
    iv. The Enclosed Farmed Landscape;
    v. Rock Habitats;
    vi. Individual Species.

    The classification of existing wildlife sites against these habitat groups has been undertaken as part of the current phase (Table 9).

    However, such a strategy should continue to be complemented by other efforts tailored towards addressing the specific needs of communities and populations that are deemed to warrant special consideration.

Table 9. The relationship between habitat groups the Lancashire BAP and priority habitats – potential future network development.

Lancashire Ecological Network	**Lancashire BAP Plan Name**	**Priority Habitats** NERC Act 2006 Section 41
Coastal Habitats	Salt Marsh and Estuarine Rivers	Coastal saltmarsh Coastal sand dunes Coastal vegetated shingle Intertidal mudflats Maritime cliff and slopes
The Farmed Landscape	Arable Farmland	Arable field margins Traditional orchards Hedgerows Eutrophic standing waters
Lakes and Ponds		Eutrophic standing waters Mesotrophic lakes Oligotrophic and dystrophic lakes Ponds
Rivers, Streams and Canals	Rivers and streams	Eutrophic standing waters Rivers
Rock Habitats	Limestone Pavement	Maritime cliff and slopes Inland rock outcrop and scree habitats Limestone pavements

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