thomson
ecology



Habitat Connectivity / Ecological Networks Mapping for the South Downs National Park

For

South Downs National Park Authority

Project No. J SDN 102 / 001 / 001

May 2015

London & South East
Compass House
Surrey Research Park
Guildford
GU2 7AG . UK

t: +44 (0)1483 466 000

North & Borders
Calls Wharf
2 The Calls
Leeds
LS2 7JU . UK

t: +44 (0)113 247 3780

Wales & South West
Williams House
11-15 Columbus Walk
Cardiff
CF10 4BY . UK

t: +44 (0)2920 020 674

Scotland
20-23 Woodside Place
Glasgow
G3 7QF . UK

t: +44 (0)141 582 1333

Midlands & East
Business Centre East
Fifth Avenue
Letchworth
SG6 2TS . UK

t: +44 (0)1462 675 559

Enquiries

e: enquiries@thomsonecology.com

w: www.thomsonecology.com

Project Number	Report No.	Revision No.	Date of Issue
JSDN102	001	001	Date

	Name	Signature	Position
Written by:	Phil Lomax		Principal Ecologist
Checked by:			
Approved by:	Tim Donoyou		GIS Manager

Contents

Figures

Tables

Graphs

1. Summary and Main Recommendations

1.1 Summary

1.1.1 The South Downs National Park Authority (SDNPA) is responsible for leading the development and implementation of the South Downs Partnership Management Plan (SDPMP) and the Local Plan. The SDNPA works with a wide range of stakeholders to help achieve the vision for the National Park and to deliver National Park Purposes and Duty.

1.1.2 A key priority for the SDNP is to restore an ecologically-functional network of semi-natural habitats (a critical part of our natural capital) across the South Downs National Park which delivers a wide range of ecosystem services. This interconnected matrix of habitats will be highly valued and appropriately used by a wide range of local people and visitors, and sustainably managed to secure the benefits for future generations.

1.1.3 This project is of high importance and urgency as it is a required piece of evidence for the Local Plan. This is a statutory requirement under the National Planning Policy Framework (NPPF). The NPPF says that: "planning policies should identify and map components of the local ecological networks, including the hierarchy of international, national and locally designated sites of importance for biodiversity, wildlife corridors and stepping stones that connect them and areas identified by local partnerships for habitat restoration or creation"

1.1.4 The outputs from this project will help the SDNPA to assess progress against policies and objectives for the SDPMP and Local Plan, help target land management and development management decisions and deliver a green infrastructure strategy. It will also be helpful in developing and evaluating project objectives.

1.1.5 The project has two key objectives:

- Development and application of a model to assess semi-natural habitat connectivity across the SDNP; and
- A queriable map-based habitat potential model for the South Downs National Park which highlights locations which should be suitable for the creation, connection and restoration of agreed priority habitats.

1.1.6 This project complements and builds on the spatial (ArcGIS) heathland and wetland habitat potential work already completed by SXBRC for the SDNPA.

1.1.7 The first stage of the project reviewed current literature and best practice to recommend the development of a bespoke model combining the graph theory, least cost and barrier modelling approaches to best map existing semi-natural habitat connectivity across the whole of the SDNP.

1.1.8 The second stage of the model collated all the required data and developed a model to meet the SDNPA requirements directed by the findings of the stage 1 review.

1.1.9 The third stage reviewed and refined the habitat opportunity models for lowland calcareous grassland, wooded heathland and wetland habitats created by SxBRC with currently available data and applied them to the whole of the SDNP. Using the same approach and methodology a model was created to identify opportunities for Lowland Mixed Deciduous Woodland, Lowland Beech and Yew Woodland, Wood Pasture and Parkland and Traditional Orchards.

1.1.10 The outputs of the Habitat Opportunity Models were analysed, prioritised and categorised into the different components of an ecological network – connectors, extensions, stepping stones and new standalone sites.

1.2 Main Recommendations

1.2.1 This project has addressed evidence and data gaps for habitat connectivity and habitat opportunity mapping in the South Downs National Park but due to the importance and nature of the subject and size of the SDNPA study area it is felt this should just be the beginning of a long term process.

1.2.2 Key next steps could be:

- A presentation of the results to and discussion with key SDNPA staff to assess how the results can be best used within and provide best value to the SDNPA. This would undoubtedly raise questions and ideas for future development and applications;
- A formal review and comparison with the SxBRC models, input data and results as a validation exercise;
- Integration with the other landscape scale models currently in development including the visual assessments (Land Use Consultants) and ecosystem services (EcoServe) SDNP wide;
- Collation, capture and use of historic land use / cover data (OS Tithe Maps) which has not been used in this project but would add significant value to future model development;
- Improving and validating the input data from SxBRC and HBiC particularly the Protected / Priority Species records and the Broad BAP Habitat layer would benefit this exercise as would more wider ecological assessments across the SDNP, Hampshire and Sussex;
- If required, a more detailed and indicator species focussed approach could be taken but this would be dependent on sourcing reliable, high resolution and complete species records datasets as described above;
- Ground truthing and practical assessment of the potential habitat opportunity areas should be undertaken;
- Habitat quality data for some habitats, for example Environment Agency WFD for rivers and streams or Natural England SSSI Condition Monitoring, could add significant value to the models and really target where the best and most influential interventions could be made;
- Consideration of how the potential habitat opportunity areas could be implemented in terms of Countryside Stewardship Schemes, designated sites creation / extension and biodiversity offsetting; and
- Wider consultation with SDNPA stakeholders and interest groups to present and discuss how the model can be best developed for use by all to significantly improve the semi-natural habitat quality and connectivity within the SDNP.

2. Introduction

2.1 Project Background

2.1.1 The South Downs National Park Authority (SDNPA) was established on 1st April 2011 and is responsible for administering the functions of England's newest National Park. These are to:

- conserve and enhance the natural beauty, wildlife and cultural heritage; and
- promote opportunities for the understanding and enjoyment of the special qualities of the National Park by the public.

2.1.2 If there's a conflict between these two purposes, conservation takes priority. In carrying out these aims, the South Downs National Park (SDNP) is also required to seek to foster the economic and social well-being of local communities within the National Park.

2.1.3 The SDNP boundary is shown in Figure 1 and it covers 1,600 square kilometres of land protected for its special qualities – it's beautiful and diverse landscapes of ancient woodlands, heathland, rivers, iconic cliffs and coast, the rolling chalk Downlands, and the Western Weald – supporting a network of unique and internationally important wildlife. It includes:

- 13 sites of European nature conservation importance;
- 15% of the land area is designated for its nature conservation interests;
- 24% of the land is covered by woodland of which 10% is ancient woodland;
- 4% of the land is covered by chalk grassland;
- 85% of the land is farmed consisting mainly of arable land (44%) and permanent pasture (37%); and
- there are 15 different landscape types within the SDNP.

2.1.4 A Partnership Management Plan sets out a shared vision for how the SDNPA, its partners and stakeholders would like the National Park to be in the future. It includes 11 long-term outcomes, and provides a framework for communities, landowners, charities, businesses and public bodies to work together to make this vision and these outcomes a reality. It focuses on where partnership action can make a tangible difference over the next five years.

2.1.5 Preparation of the Plan has been led and co-ordinated by the SDNPA working jointly with a high-level stakeholder group – the South Downs Partnership. It is designed to stimulate local action, influence the major streams of public and private investment into the National Park, and align with the policies and programmes of other public bodies. It will drive the Authority's own business and operational plans, and provides the starting point for the development of the policies in the Local Plan which is currently being prepared.

2.1.6 The Partnership Management Plan identifies the maintenance of a resilient ecological network as a major issue for which action is required: *"Although many nationally and internationally important species and habitats still exist in the National Park, its ecosystems have, like those across the UK, suffered significant damage over the last 150 years through loss of habitats, their fragmentation and degradation. Additional factors – such as climate change, new diseases and invasive species – add to this pressure. It is clear that in order to create more resilient ecosystems, habitats will need to be better managed, bigger and more joined up. Species will need to be able to move through the landscape if they are to adapt to change and survive. This means looking well beyond nature reserves and working across the wider farmed countryside".*

2.1.1 To address this issue Outcome 3 of the Partnership Management Plan is to ensure that by 2050: *"A well-managed and better connected network of habitats and increased population and distribution of priority species now exist in the National Park, measured by:*

- Area, condition and connectivity of target priority habitats;
- Population and distribution of target priority species;
- Distributions of target non-native invasive species; and
- Percentage of water bodies achieving 'good' or 'high' status or potential"

2.1.2 To help deliver this outcome, the following policies of the Partnership Management Plan have been agreed:

- Policy 4 to: "Create more, bigger, better-managed and connected areas of habitat in and around the National Park, which deliver multiple benefits for people and wildlife".
- Policy 2 to: "Develop landscape-scale partnerships and initiatives to focus on enhancing the key ecosystem services delivered by the National Park"; and
- Policy 5 to: "Conserve and enhance populations of priority species in and around the National Park, delivering targeted action where needed".

2.1.3 The SDNPA is the local planning authority responsible for setting local planning policy for the whole of the National Park. Preparation of the Local Plan for the SDNP is underway and it is planned to publish the Preferred Options in October 2015. The Local Plan will reflect and set out further policy and action to help implement the outcomes and policies of the Partnership Management Plan.

2.2 Ecology Background

2.2.1 This project will make use of all relevant available data and information on landscape and ecology, and especially the habitat opportunity model developed by the Sussex Biodiversity Record Centre (SxBRC) previously used to produce heathland habitat opportunity maps for the Heathlands Reunited project area, and wetland habitat opportunity maps for the Arun & Rother river catchment area. Similar biodiversity opportunity area mapping for the Hampshire area of the SDNP will be obtained from the Hampshire Biodiversity Information Centre (HBiC).

2.3 The Brief and Objectives

2.3.1 A key priority for the SDNPA is to restore an ecologically-functional network of semi-natural habitats across the SDNP which delivers a wide range of ecosystem services. This interconnected matrix of habitats will be highly valued and appropriately used by a wide range of local people and visitors, and sustainably managed to secure the benefits for future generations.

2.3.2 In order to measure improvements in semi-natural habitat connectivity across the SDNP, the SDNPA must first set an accurate baseline. The primary aim of this project is therefore to develop a model to measure semi-natural habitat connectivity across the SDNP. Another key outcome of the project will be to create habitat opportunity maps for agreed priority habitats, building on previous habitat opportunity mapping work such as heathland opportunity mapping for the Heathlands Reunited Project and wetland habitat mapping for the ARC Project.

2.3.3 This project is of high importance and urgency as it is a required piece of evidence for the Local Plan. This is a statutory requirement under the National Planning Policy Framework (NPPF).

2.3.4 Key elements of the project will be to:

- Develop a suitable model for assessing semi-natural habitat connectivity across the SDNP (researching best practice and all the currently available tools and models for assessing habitat connectivity in the UK);
- Apply the habitat connectivity model to the SDNP to derive a current figure for habitat connectivity (for example by using a scale of 0-1 where zero equals no habitat connectivity and one equals completely unbroken semi-natural habitat); and
- Adapt the habitat opportunity model already developed for heathland and wetland in the SDNP for other agreed priority habitats in the SDNP (producing GIS maps which can be overlaid).

2.3.5 The two key outputs of this piece of data and evidence work will be:

- Development and application of a model to assess semi-natural habitat connectivity across the SDNP; and
- A queriable map-based habitat potential model for the SDNP which highlights locations which should be suitable for the creation, connection and restoration of agreed priority habitats. The agreed priority habitats will include chalk grassland, heathland, semi-natural woodland, hedgerows, freshwater priority habitats such as rivers and streams, and coastal priority habitats such as saltmarsh. The full list of priority habitats for this project were agreed at the project start-up meeting.

2.3.6 The Habitat Opportunity Model must complement the existing heathland and wetland opportunity models (the same model must be applied). The model must identify the following:

- Areas of high opportunity for ecosystem service delivery;
- Areas of potential conflicting opportunity (e.g. an area with high potential to create heathland habitat may also be an area with high potential to create woodland habitat)
- Potential matrix of all semi-natural habitats across the SDNP (i.e. where are the best opportunities to create an interlinked mosaic of semi-natural habitats?)

2.3.7 The final output of this project will be a detailed project report (including maps) and accompanying GIS layers, following the format of previous Habitat Opportunity Mapping reports for the SDNP.

2.3.8 Thomson Ecology was commissioned to undertake this project by the SDNPA on the 23rd of October 2014. In order to effectively deliver the required outcomes and outputs from this project, Thomson Ecology proposed a methodology framework in its tender document JSDN102-001 and following the start-up meeting held between Thomson Ecology and the SDNPA on the 6th November 2014 this framework was agreed.

3. Legal and Planning Policy Considerations

3.1.1 The SDNPA is the local planning authority responsible for setting local planning policy for the whole of the National Park. Preparation of the Local Plan for the SDNP is underway and it is planned to publish the Preferred Options in October 2015. The Local Plan will reflect and set out further policy and action to help implement the outcomes and policies of the Partnership Management Plan.

3.1.2 The NPPF requires Local Planning Authorities to:

- Paragraph 114 - set out a strategic approach in their Local Plans, planning positively for the creation, protection, enhancement and management of networks of biodiversity and green infrastructure (GI).
- Paragraph 117 - identify and map components of the local ecological networks.

3.1.3 By mapping existing habitat networks including existing priority habitats and their connectivity and opportunities for habitat creation, this project will both meet the NPPF requirement for identifying and mapping ecological networks and provide the evidence base for spatial planning that identifies where new development can take place that will protect and enhance habitat connectivity now and into the future.

3.1.4 Paragraph 009 of the National Planning Practice Guidance (NPPG, 2014) sets out the approach to meeting the requirements of the NPPF as described above. The components of an ecological network are explained at section 2.12 of the Natural Environment White Paper, 2011.

3.1.5 Relevant evidence in identifying and mapping local ecological networks includes:

- the broad geological, geomorphological and bio-geographical character of the area, creating its main landscapes types;
- key natural systems and processes within the area, including fluvial and coastal;
- the location and extent of internationally, nationally and locally designated sites;
- the distribution of protected and priority habitats and species;
- areas of irreplaceable natural habitat, such as ancient woodland or limestone pavement, the significance of which may be derived from habitat age, uniqueness, species diversity and/or the impossibilities of re-creation;
- habitats where specific land management practices are required for their conservation;
- main landscape features which, due to their linear or continuous nature, are important for the migration, dispersal and genetic exchanges of plants and animals, including any potential for new habitat corridors to link any isolated sites that hold nature conservation value, and therefore improve species dispersal;
- areas with potential for habitat enhancement or restoration, including those necessary to help biodiversity adapt to climate change or which could assist with the habitats shifts and species migrations arising from climate change;
- an audit of green space within built areas and where new development is proposed;
- information on the biodiversity and geodiversity value of previously developed sites and the opportunities for incorporating this in developments; and
- areas of geological value which would benefit from enhancement and management.

3.1.6 Local Nature Partnerships can be a useful source of information for existing ecological networks.

3.1.7 Paragraph 017 of the NPPG states that biodiversity maintenance and enhancements through the planning system have the potential to make a significant contribution to the achievement of Biodiversity 2020 targets.

3.1.8 Biodiversity enhancement in and around development should be led by a local understanding of ecological networks, and should seek to include:

- habitat restoration, re-creation and expansion;
- improved links between existing sites;
- buffering of existing important sites;
- new biodiversity features within development; and
- securing management for long term enhancement.

3.1.9 These objectives are based on achieving the recommendations of the Lawton Review (Lawton 2010). Lawton stated that:

"the essence of what needs to be done to enhance the resilience and coherence of England's ecological network can be summarised in four words: more, bigger, better and joined. There are five key approaches which encompass these and also take account of the land around the ecological network. We need to:

- improve the quality of current sites by better habitat management;
- increase the size of current wildlife sites;
- enhance connections between, or join up, sites, either through physical corridors or through 'stepping stones';
- create new sites; and
- reduce the pressures on wildlife by improving the wider environment, including through buffering wildlife sites."

3.1.10 The Natural Environment White Paper (2011) supports this practical vision for addressing the fragmentation of the natural environment, by restoring ecological networks across the country. The approach is based on five components to be implemented at the landscape scale:

- Core areas of high nature conservation value which contain rare or important habitats or ecosystem services. They include protected wildlife sites and other semi-natural areas of high ecological quality;
- Corridors and ‘stepping stones’ enabling species to move between core areas. These can be made up of a number of small sites acting as ‘stepping stones’ or a mosaic of habitats that allows species to move and supports ecosystem functions;
- Restoration areas, where strategies are put in place to create high-value areas (the ‘core areas’ of the future) so that ecological functions and wildlife can be restored;
- Buffer zones that protect core areas, restoration areas and ‘stepping stones’ from adverse impacts in the wider environment; and
- Sustainable use areas, focused on the sustainable use of natural resources and appropriate economic activities. Together with the maintenance of ecosystem services, they ‘soften’ the wider countryside, making it more permeable and less hostile to wildlife.

4. Stage 1 – Literature and Best Practice Review

4.1 Introduction

4.1.1 The first stage of the project required research into and a review of best practice and all currently available tools and models for assessing habitat connectivity, and principally those models used in the UK.

4.2 Approach and Methodology

4.2.1 We identified a range of reports and scientific papers setting out descriptions of or reviewing the merits of habitat connectivity modelling projects .These, and other sources, were consulted and reviewed to assess the relative strengths and weaknesses of different modelling approaches to achieve the outcomes and outputs required from this project and set out at Section 2.

4.2.2 Our approach to reviewing existing models was to assess them against their ability to identify and enable the future planning of the five components of an ecological network as identified in the Lawton Report, 2010 and the Natural Environment White Paper 2011:

- Core Areas;
- Corridors and 'stepping stones';
- Restoration areas;
- Buffers zones; and
- Sustainable use areas – 'softening the matrix'.

4.2.3 The models were reviewed and compared against:

- Each component of an ecological network as identified by the Lawton Report;
- Appropriateness and applicability to the South Downs National Park;
- The data currently available for the SDNP area; and
- Data and evidence gaps.

4.3 Findings

4.3.1 Landscapes and the ecological networks they support are becoming increasingly fragmented by changes in the use and management of the landscape, the intensification and extensification of use and by development. In consequence the area of natural and semi-natural habitats has reduced, anthropogenic edges have increased, ecological connectivity has been reduced and the heterogeneity of the landscape has been reduced. It is under these circumstances that 'extinction cascades' are likely to occur, especially if keystone species or entire functional groups of species are lost (Fischer and Lindenmayer, 2007). Those species with the most specialised habitat requirements and with limited ability to disperse to other suitable habitats are worst affected by habitat fragmentation and loss of ecological connectivity and are therefore put at greatest risk of localised or wider extinctions.

4.3.2 The risks to these species from anthropogenic changes to the landscape resulting in habitat loss, fragmentation and degradation are subsequently compounded by other pressures such as climate change. Typically, landscape change results in smaller, more isolated populations that are less resilient and more vulnerable to extreme weather events, to natural disasters such as fire, to disease and are at increased risk of predation (Fischer and Lindenmayer, 2007).

4.3.3 Habitat patch size, patch quality, edge effects, habitat heterogeneity and connectivity are all key parameters of ecological networks that are affected by landscape change. Typically, landscape change results in the reduction of habitat patch size, degradation of patch quality, an increase in the proportion of edge habitat to core habitat, a reduction in landscape heterogeneity and reduction in ecological connectivity (Fischer and Lindenmayer, 2007). It is therefore important when planning conservation activities to consider all of these adverse effects since they are often inter-related and inter-dependent. Likewise, their effects on species populations can be cumulative with for example reduction in patch size and or quality being compounded by the isolation of those patches.

4.3.4 Lawton (2010) concluded that there are serious shortcomings in the current ecological network in England. Many wildlife sites are too small, losses of certain habitats have been on such a scale that the remaining areas are no longer large enough to maintain biodiversity and many of the natural connections in the countryside have been degraded or lost.

Modelling of ecological networks

4.3.5 Achieving the Lawton vision requires that landscape planners and landscape managers have the tools to be able to identify where actions are best targeted to achieve the above objectives in the most effective and efficient way. Various approaches have been proposed and trialled for modelling ecological networks. Most of these seek to map connectivity (and thereby, identify the extent of fragmentation) of similar broad habitat types.

4.3.6 A problem that is soon encountered in reviewing and comparing the different approaches to mapping connectivity is in the terminology used. Fischer and Lindenmayer (2007) argue that the term 'connectivity is often used loosely, and different authors use the term in different ways. For example, Tischendorf & Fahrig (2000) considered landscape connectivity to be an attribute of landscapes that resulted from the interaction of land cover with individual species' movement rates. In contrast, Moilanen & Hanski (2001) took a metapopulation perspective and suggested that connectivity was better understood as an attribute of individual patches.

4.3.7 Other authors have distinguished between structural connectivity and functional connectivity. (Briers, 2011). Fisher and Lindenmayer (2007) attempted to resolve the confusion over terminology by identifying three distinct types of connectivity which are summarised in Table 1 below.

Table 1: Connectivity Definitions (after Fischer and Lindenmayer, 2007)

Connectivity Type	Definition
Habitat Connectivity	Habitat connectivity is the connectedness between patches of suitable habitat for a given individual species. It may be defined at the patch scale or at the landscape scale. The term is chosen to include the word 'habitat' to emphasize its species-specific nature.

Landscape Connectivity	Landscape connectivity is a human perspective of the connectedness of native vegetation cover in a given landscape. It may be expressed using various buffer- or distance-based metrics that can be calculated from maps of human-defined land cover. The term is chosen to include the word 'landscape' to emphasize its anthropocentric nature – the concept of a landscape is a human construct.
Ecological Connectivity	Ecological connectivity is the connectedness of ecological processes across multiple scales, including trophic relationships, disturbance processes and hydroecological flows. Measurement of ecological connectivity is not straightforward and depends on which aspect of ecological connectivity is to be estimated. Despite this difficulty, ecological connectivity is an important concept that is not adequately captured by existing definitions of connectivity.

4.3.8 The three connectivity concepts are related but not synonymous. Landscape connectivity may translate into habitat connectivity for some but not all species. For example, corridors and stepping stones (i.e. small vegetation patches scattered through a landscape) always contribute to landscape connectivity, but may not be used by all native species – that is, they do not contribute to habitat connectivity for those species (Forman, 1995; Beier & Noss, 1998). Similarly, the relationship between landscape connectivity and ecological connectivity tends to be positive, but not all ecological processes are effectively facilitated through all types of landscape connectivity. For example, seed-dispersing birds used corridors in a study in South Carolina (USA). Here, enhanced landscape connectivity increased one aspect of ecological connectivity, that is, the process of seed dispersal (Levey *et al.*, 2005a). However, neither corridors nor stepping stones may effectively maintain some aspects of ecological connectivity such as natural hydrological flows or the natural spread of fire throughout a landscape.

4.3.9 In practice, landscape connectivity is the most easily manageable aspect of connectivity because it requires no detailed understanding of individual species' habitat requirements or ecological processes. Landscape connectivity may be enhanced through corridors, stepping stones, and the maintenance of a 'soft' matrix which is structurally similar to native vegetation. Despite some ecological risks such as potentially facilitating the spread of introduced species, increased landscape connectivity is usually more likely to have desirable effects on native species and ecological processes than undesirable effects.

4.3.10 Briers (2011) uses assessment measures of landscape connectivity as the basis for his review of the strengths and weaknesses of modelling approaches. He defines landscape connectivity as the extent to which the landscape allows or impedes movement among patches of a specified habitat type - a definition which confusingly corresponds with Fisher and Lindenmayer's definition of 'habitat connectivity'.

4.3.11 Briers highlights that connectivity between habitat patches can be seen in both structural and functional contexts as summarised in Table 2 below:

Table 2: Connectivity Definitions (after Briers, 2011)

Connectivity Type	Definition
Structural Connectivity	Structural connectivity measures are based on the spatial distribution, size and number of fragments of habitat. In essence a structurally connected landscape is one where patches of habitat are directly linked so that species can move between patches of habitat without having to travel through the intervening habitat or matrix, which to a greater or lesser degree is unsuitable for the species in question.
Functional Connectivity	Functional connectivity in contrast, does not require direct connections between patches or fragments, as long as the distances between patches are not so high, and intervening land-uses are not so hostile, as to prevent movement between patches. Intuitively, for some species, notably those with relatively poor dispersal abilities, certain types of land-use may be easier to move through than others, i.e. there are different 'costs' to an individual to movement through different land-uses. Land-use types may have a high cost to a particular species if they lack, for example, food or refuges, or have an increased risk of predation. Promotion of functional connectivity involves considering the extent to which it is possible to prioritise the conservation of existing relatively low-cost land-uses (i.e. those which are easy for a species to move through) between habitats, and promote changes in land-use through management interventions to reduce the cost of species movement.

4.3.12 Briers (2011) summarises models of connectivity into three main types of habitat network model:

- Least-cost models which measure the ability or difficulty of a species to move across a landscape. These are the most common in the UK and an example is the widely used BEETLE developed by Forest Research;
- Graph theory models which represent an ecological network as a series of nodes and edges which make up the graph network; and
- Spatially-Explicit Population Models (SEPMs) which combine a detailed understanding of a species population dynamics across a particular landscape.

Least-cost Models

4.3.13 *What are least-cost models?* - They are a specific type of graph-theory model, which represent landscape permeability or resistance: the effect of land-use on the ability of a species to move across the landscape. Most UK habitat network modelling is based on least-cost models.

4.3.14 *What do they measure?* - They seek to measure the degree of *functional connectivity* between different habitat patches.

4.3.15 *How do they work?* - Different land-uses are assigned different permeability values, which reflect the relative cost or difficulty for a species to travel through that land-use. Traversing an area of high-cost matrix will reduce the distance that a species is able to travel, and in extreme cases may prevent any movement i.e. be a complete barrier. This is known as the cost-distance and can be conveniently calculated in most GIS software applications using standard algorithms. The extent to which patches of habitat are connected depends on the nature of the intervening land-uses. Least-cost habitat networks are defined as those areas of land, including the habitat patches, where the cumulative cost of movement is less than the maximum distance that a species can travel. If such areas between two patches of habitat meet at any point then the patches are considered functionally connected.

4.3.16 *How effective are they?* - As with any model, their effectiveness is constrained by the quality of the data that is used. A key feature of all least-cost models is that they seek to assess the degree of connectivity between different habitat patches in the landscape for a particular species or group of species. This requires understanding and data on the dispersal distances of those species . Such data is significantly lacking. Briers (2011) noted that published data on dispersal distances was only available for 28 out of 1245 species of conservation concern. There is also a need for empirical data on the ease of movement for the species being assessed through different types of vegetation. Briers (2011) notes that with a few exceptions, such data is not available. Therefore, the fundamental data on which effective least-cost modelling depends is virtually non-existent. This is a major limitation on the effectiveness of such models.

4.3.17 Due to this lack of data, use is made instead of expert opinion through the Delphi process which co-ordinates and moderates the opinions of a group of experts. In some applications of least-cost models in the UK (e.g. Catchpole 2006), the limitations of least-cost analyses are clearly stated, with emphasis placed on the ‘fuzziness’ inherent in the resultant network maps and the importance of considering this when interpreting the network analyses for land-use planning. However the impact of this uncertainty is not well communicated when simply viewing the network maps, which in general place clear and well defined boundaries on the habitat networks, and only give outputs based on either single estimates or mean/median permeability values, with no visual indication of the underlying uncertainty. In addition, parameter uncertainty will not affect all parts of the network configuration equally.

4.3.18 Briers (2011) summarises studies which have demonstrated that even small changes in the expert assessment of dispersal distances and landscape permeability for a species, can result in significant differences in the results and can therefore potentially result in connectivity models significantly underestimating or over-estimating connectivity. Briers (2011) however makes some pragmatic proposals for dealing with this inherent uncertainty. Firstly he notes that studies have demonstrated that it is the relative (i.e. rank order) values of landscape permeability that are key factors in determining model outputs of connectivity. Therefore, he suggests, that as long as relative permeability values are broadly appropriate, the relative extent of different networks should be reasonably robust.

4.3.19 Secondly, he recommends least-cost models use a range of values for dispersal and landscape permeability so that connectivity mapping provides minimum, maximum and mean measures of connectivity giving a visual representation of the uncertainties inherent in the data.

4.3.20 There are other generic limitations common to most models that are discussed together later in this report.

Graph theory models

4.3.21 *What are graph theory models? -* They are models of habitat networks and the degree of connectivity between habitat patches in the network.

4.3.22 *What do they measure? -* They measure the degree of *structural connectivity* between habitat patches via the number and strength of the links between them and also identify the most important nodes (habitat patches) in the network.

4.3.23 *How do they work? -* They represent habitat networks as a series of nodes (patches) and edges (links) which together make up the network graph. Two nodes are linked if dispersal is possible between them based on actual distance or cost distance.

4.3.24 *How effective are they? -* Graph theory models do not require the levels of data and computation required for SEPM's (see below) . However, as with least-cost modes, they do still require some kind of measurement of dispersal distances for a species or group of species with all the uncertainties this entails (see above).

4.3.25 There main advantages over least cost models is that habitat patches are weighted for both size and ecological value - important attributes in any ecological network and which are not considered in least cost models. It also identifies key nodes (the most habitat patches with the most links) based on their number of links to other nodes. In addition, it identifies the frequency with which a patch falls between other pairs of patches in the network (called 'betweeness'). Together these two measures show the degree of connectivity for any given node in relation to all other nodes. These in turn are important in assessing the value or potential of habitat nodes as 'stepping stones' in the habitat network (Minor and Urban, 2007).

Spatially -Explicit Population Models (SEPM's)

4.3.26 *What are SEPM's? -* The most sophisticated and complex models so far developed for modelling ecological connectivity. They most closely represent reality because they consider a large number of dependant variables simultaneously.

4.3.27 *What do they measure? -* They measure the degree of *population connectivity* in a given landscape.

4.3.28 *How do they work? -* SEPMs represent a landscape using patches or cells and explicitly identify the location of every object of interest (e.g. individual, population, cell, or habitat patch). These common models can simulate birth, mortality, and movement of individuals or populations and are often considered the best means of predicting the response of organisms to habitat change or other broadscale landscape processes. However, their utility is constrained by their computational and data requirements.

4.3.29 *How effective are they? -* Because they are very computationally intensive, they are limited in both number of habitat patches and individuals they can simulate. They also require knowledge of species' demographic parameters such as mortality and fecundity rates, in addition to knowledge of dispersal and other behaviours. These data are often difficult to obtain and can include much uncertainty, which can render the results unreliable (Minor and Urban, 2007).

Barrier Modelling

4.3.30 In addition to the three main models identified by Briers (2011) it is important to consider other more recent models that are being developed to help understand habitat connectivity. In particular, barrier modelling has significant relevance in seeking to deliver the key outcomes of this project for the SDNP.

4.3.31 *What is barrier modelling?* - As its name implies, this models not how permeable a landscape is (as in the above models) and therefore the extent to which the landscape allows or impedes movement of species through the landscape, but seeks to identify those elements of the landscape that are the most significant barriers to habitat connectivity. It has been pioneered by McRae et al (2012).

4.3.32 *What does it measure?* - Essentially it measures where habitat restoration or re-creation could prove most effective in restoring habitat connectivity in a given landscape.

4.3.33 *How does it work?* - The model uses GIS neighbourhood analyses in conjunction with effective distance analyses to detect barriers that, if removed, would significantly improve connectivity. Applicable in least-cost, circuit-theoretic, and simulation modelling frameworks, the method detects both complete (impermeable) barriers and those that impede but do not completely block movement.

4.3.34 *How effective is it?* - Barrier mapping complements corridor mapping by broadening the range of connectivity conservation alternatives available to practitioners. The method can help practitioners move beyond maintaining currently important areas to restoring and enhancing connectivity through active barrier removal. It can inform decisions on trade-offs between restoration and protection; for example, purchasing an intact corridor may be substantially more costly than restoring a barrier that blocks an alternative corridor. And it extends the concept of centrality to barriers, highlighting areas that most diminish connectivity across broad networks. Identifying which modelled barriers have the greatest impact can also help prioritise error checking of land cover data and collection of field data to improve connectivity maps. Barrier detection provides a different way to view the landscape, broadening thinking about connectivity and fragmentation while increasing conservation options.

Comparison of the potential effectiveness of the different ecological network modelling approaches to achieve the objectives of the SDNPA

4.3.35 The review of the main ecological network models has identified relative strengths and weaknesses of each approach when assessing the models relative usefulness in delivering the outcomes required by the SDNPA . The key issues identified are summarised in Table 3 below:

Table 3: Some common issues of ecological network models

Issue	Least Cost Models	Graph Theory Models	SEPM's	Barrier Models
1. Do not differentiate between habitat patches of different sizes and values - assume that all similar habitats have similar values in the ecological network	True	False	False	True
2. Do not explicitly consider major barriers to dispersal - either natural (e.g. soils and topography) or man made (e.g. roads)	True	True	True	False
3. Do not consider the *potential connectivity* i.e. there are connectivity models and habitat opportunity models but there doesn't seem to have been any attempt to correlate the outputs of both models to assess potential connectivity	True	True	True	False
4. Do not explicitly acknowledge the relative importance of structural connectivity - although the functioning of 'wildlife corridors' is a matter of some dispute	True	False	False	False

Model Application in the Real World

4.3.36 Lawton (2010) states that the use of such 'real world' frameworks is an essential requirement of modelling habitat connectivity: *"...we also need an appropriate geographical framework, which takes account of both natural and cultural heritage, including historic land use, hydrology, soils, geology and ecology. National Character Areas provide this framework and we have mapped the relative fragmentation of different parts of England using them. It confirms that major differences exist in landscape connectivity across England, with clear implications for what needs to be done to create a more resilient ecological network in different parts of England. The priorities for action in an area with large amounts of relatively well-connected habitat remaining will often be different to those in an area where sites tend to be small and isolated".*

4.3.37 The basic models described above have been used in slightly different ways for different applications and there have been some interesting and novel development of the basic model types. For example, Catchpole (2006) uses Landscape Character Assessment (LCA) as a framework for habitat connectivity assessment. 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).

4.4 Recommendations

4.4.1 The literature and best practice review has shown that there is no single model that would appear to be capable of assessing semi-natural habitat connectivity at a landscape scale and delivering the outcomes and outputs required by the SDNPA. However, the different models each have the potential to deliver elements of the outcomes and outputs required. We, therefore, propose to develop a bespoke model which combines the most useful elements of the graph theory, least cost and barrier models.

5. Stage 2 - Modelling Existing Semi-Natural Habitat Connectivity within the South Downs National Park

5.1 Introduction

5.1.1 As the research of current best practice showed a 3 stage approach to modelling existing connectivity within the South Downs National Park was completed:

- Graph Theory Model Approach – valuing existing priority habitats within the South Downs National Park;
- Least Cost Model Approach – Measuring the existing landscape permeability for habitat connectivity within the South Downs National Park; and
- Barrier Model Approach – Identifying the current key limitations to priority habitat connectivity within the South Downs National Park.

5.1.2 Each of these steps was undertaken individually and resulted in three GIS layers showing a 'continuous surface' of semi-natural connectivity by model type which, as one would expect, did show variations in connectivity type across the whole of the South Downs National Park.

5.1.3 The 3 layers were combined in ArcGIS to create a final map of existing semi-natural habitat connectivity across the South Downs National Park.

5.2 Semi-Natural Habitat Data Source

5.2.1 The primary source of semi-natural habitat data for this project was the Natural England Priority Habitat Inventory Version 2 dataset downloaded from the Natural England website (http://www.gis.naturalengland.org.uk/pubs/gis/GIS_register.asp) on the 11th December 2014.

5.2.2 Other datasets, such as the SDNPA Broad BAP habitat dataset, were considered but the quality and reliability of the information contained within them was largely unknown and it was beyond the scope of this project to clean and quality assure datasets prior to use. In addition, the Natural England Priority Habitat Inventory dataset has an update programme which includes information provided by statutory bodies, local biodiversity records centres and councils so the models can be re-run with each new release.

5.2.3 The Natural England Priority Inventory dataset will be referred to as NE PHI.

5.2.4 The NE PHI was clipped to the SDNP boundary and Figure 2 shows the distribution of the NE PHI across the SDNP.

5.3 Priority Habitat Data Pre-Processing - Habitat Polygons and Parcels

5.3.1 The NE PHI dataset is derived from Ordnance Survey Mastermap (OSMM) Topographic Area and the OSMM polygons provide the mapping unit or boundary for each priority habitat class. In many cases there are adjacent OSMM polygons with the same PHI classification which should, for the purposes of this project, be considered as the same semi-natural habitat parcel. In addition, many woodlands and large grassland habitat complexes have small, linear features dividing them such as tracks, ditches and streams which would not limit connectivity significantly for the majority of flora and fauna species and therefore neighbouring habitat polygons should be considered as the same habitat parcel.

5.3.2 To overcome this issue we developed a tool in ArcGIS to create habitat parcels from the PHI polygons. For each PHI polygon the tool:

- Searched to find all 'contiguous' neighbouring polygons of the same habitat type within 5m to form a habitat parcel;
- Calculated the number of polygons, the total area and polygon ids for each habitat parcel; and
- Created a new derived, dissolved habitat parcel layer for each priority habitat type.

5.3.3 This new NE PHI layer was used as the input for all habitat connectivity and opportunity modelling.

5.4 Existing Semi-Natural Habitat Connectivity Modelling - General Approach

5.4.1 The general approach to modelling semi-natural habitats within the SDNP was one that assessed them relative to each other and other selected ecological variables but they have not been measured or compared relative to the actual biodiversity value or condition of each parcel. This was beyond the scope of this project as a desk based assessment.

5.4.2 A requirement of the project was to coordinate all relevant spatial and physical characteristic data into a single location as a reusable database. Therefore, models and datasets were created at each stage with the following features:

- An ArcGIS map document (*.mxd) was created to collate and symbolise each of the relevant layers and to allow spatial and attribute queries to interrogate the data further as required;
- A single geodatabase was created for each modelled habitat which contained all of the input and output datasets so that the model process can be tracked, repeated and results verified;
- A wide ranging search was undertaken to source all available data layers to exactly match or provide a suitable surrogate to the SxBRC model inputs;
- A raster based approach was undertaken, with a cell size of 10m, as this is the most efficient method of managing continuous datasets across a large scale area such as the SDNP. The 10m resolution significantly improves the level of detail represented in the model and therefore should result in more accurate and reliable results; and
- The vector layers were processed to assign the correct weighting factors to each polygon and then converted to raster grids for overlaying and analysis.

5.5 Graph Theory Model Approach - Valuing Existing Priority Habitats

5.5.1 The graph theory model approach measures and scores the habitat connectivity of existing habitat parcels through an assessment of their ecological value and it was felt that this was a very important first step in the creation of a South Downs National Park habitat connectivity model.

- The best practice research and available data review identified the following key attributes to be included in the graph theory model assessment:
  - Size - it is assumed that larger sites are of better quality, more robust, support a greater range of species and provide a more significant role in landscape scale habitat connectivity;

- Designation – it is assumed that if a priority habitat is designated then it will be of high quality and as importantly be under positive management for biodiversity protection and enhancement;
- Proximity to other patches of the same priority habitat type;
- Proximity to other patches of a different priority habitat type – this recognises the importance of habitat mosaics within an ecological network;
- Number of Priority Species Records – total count of priority species records so the same species can be counted multiple times;
- Diversity of Priority Species Records – total count of unique priority species records; and
- Proximity to Non Semi-Natural Habitats such as urban areas and intensive agriculture.

5.5.2 The following datasets were used to help classify and score the selected factors:

- Natural England designated sites – Ramsar, Special Protection Areas, Special Areas of Conservation, National Nature Reserves, Sites of Special Scientific Interest and Local Nature Reserves;
- Locally (SxBRC and HBIC) designated sites – SNCIs and SINCs;
- Protected and Priority Species Records;
- South Downs National Park Broad Habitat Types; and
- Ordnance Survey Mastermap.

5.5.3 Attribute fields were added to the NE PHI layer table for each factor and populated through a series of spatial and database queries.

5.5.4 The scores were then assigned through expert opinion for overall importance of each variable, the parcel size and level of designation but also through a statistics based assessment for the neighbouring priority habitat types and priority species. The whole range of values (number of neighbouring priority habitat parcels or count of priority species records) for each variable was obtained and then divided up by the ‘natural break’ statistic and scores assigned from this. This approach is justified as it allows the best means of assessing the variation of the quality of priority habitat parcels across the whole of the South Downs National Park.

5.5.5 Table 4 shows the seven variables assessed, the total score available for each and the breakdown of scores by variable value. The highest total score available was 100.

Table 4: Attributes assessed as part of the graph theory model.

Variable		Score	Total Score Available
Size of Habitat	> 763 hectares	20	**20**
	370 - 762 hectares	16	
	163 - 369 hectares	12	
	65 - 162 hectares	8	
	15 - 64 hectares	5	
	< 15 hectares	2	
Designation	International - Ramsar, SPA or SAC	25	**25**
	National - NNR or SSSI	20	
	Local - LNR, SINC, SNCI or Ancient Woodland	10	
	None	5	
Number of Priority Habitat polygons of <u>same</u> type within 100m	> 24	15	**15**
	18 - 23	12	
	13 - 17	8	
	8 - 12	6	
	4 - 7	4	
	1 - 3	2	
	0	0	

Number of Priority Habitat polygons of different type within 100m	> 40	10	**10**
	27 - 39	8	
	17 - 26	6	
	10 - 16	4	
	5 - 9	2	
	1 - 4	1	
	0	0	
Total Number of Priority Species Records	> 459	10	**10**
	164 - 458	8	
	47 - 163	5	
	1 - 46	2	
	0	0	
Diversity of Priority Species Records	> 139	10	**10**
	164 - 458	8	
	47 - 163	5	
	1 - 46	2	
	0	0	
Proximity to Non Semi-Natural Habitats	> 615m	10	**10**
	358 - 614m	8	
	178 - 357m	6	
	54 - 177m	4	
	0 - 53m	2	
Grand Total			**100**

5.6 Least Cost Model Approach

5.6.1 The least cost model approach maps and analyses the permeability of landscapes and the degree of resistance to movement between habitat patches and was completed as the second stage of assessing habitat connectivity across the SDNP.

5.6.2 The primary input to the least cost model was the priority habitat parcel layer created during the graph theory stage above and two key processes were undertaken:

- The score attribute for the habitat parcel layer was interpolated using the Inverse Distance Weighted (IDW) algorithm to create a continuous raster surface showing theoretical quality of semi-natural habitat across the SDNP. This highlighted areas of particularly good or bad quality priority habitat but was flawed because it did not take into account any function of distance;
- A Euclidean distance surface of the habitat parcel layer was created to show proximity to semi-natural habitat across the whole of the SDNP and this was graded on a scale of 0 to 1. This highlighted areas particularly rich or deficient in semi-natural habitat.

5.6.3 The two raster layers created above were then multiplied together to map semi-natural quality and proximity across the whole of the SDNP.

5.6.4 It is acknowledged that this is a simplified approach to least cost modelling and only considers that the factors and scores calculated by graph theory approach depreciate with distance from a semi-natural habitat parcel the but the assignment of weighting factors to different land use types was undertaken as part of the barrier model approach described below.

5.7 Barrier Model Approach

5.7.1 The barrier model approach identifies areas which impede movement between ecological important areas and complements the graph theory and least cost methods which identify best movement routes.

5.7.2 To complete this for the whole of the SDNP a continuous barrier surface was created for the whole of the study area.

5.7.3 The literature review and data available determined that the following layers and weightings were assigned to create the barrier surface as shown in Table 5 below:

Table 5 – Inputs to the Barrier Model

Barrier	Weighting	Data Source
Urban Areas	0.2	OS Strategi
Intensive Agriculture	0.4	Arable land from the SDNP BAP broad habitat layer
Major Roads	0.5	OS Strategi A roads, motorways and primary routes with a 10m buffer
National Character Areas	0.5	Natural England
Rivers/Canals	0.7	EA river polyline layer with a 10m buffer
Minor Roads	0.8	OS Strategi B roads and minor roads with a 5m buffer

5.7.4 Each of the barriers were weighted depending on the strength of their negative effect on surrounding priority habitats. Barriers were weighted with a value from 0.2 to 0.8, where a lower weighting represents a barrier of stronger negative effect. It was decided not to use a value of 0 to represent a completely impassable feature for two reasons:

- The SDNP does not contain any large urban or industrial areas which would remove all possibility of habitat connectivity;
- The model is being developed at a landscape scale and is not species or habitat specific so while the barriers selected are likely to impede most semi-natural habitat and species dispersal it is unlikely that they will be a complete barrier to all.

5.7.5 The vector data layers were converted to a grid with the appropriate weighting score assigned to the cell centres. The effect of the barrier was extended to a 100m buffer and scaled by Euclidean distance so that the relative negative influence of the buffer on semi-natural habitat decreased from 1 at the barrier edge to 0 at the 100m.

5.7.6 The six barrier grids were then combined to create a barrier surface for the whole of the SDNP. Where barrier types overlapped, for example a major road within an urban area, the higher weighted barrier (i.e. lower number) took priority and it's value was maintained.

5.7.7 The output of the barrier model approach was a continuous surface of relative impedance of barrier features across the whole of the SDNP scaled from 0 (no impedance) to 0.8 (high impedance of an urban area).

5.8 Model Approach Combination – Existing Semi-Natural Habitat Connectivity

5.8.1 The final modelling stage to derive existing semi-natural habitat across the SDNP was to combine the outputs of the least cost model with the barrier model.

5.8.2 The semi-natural habitat quality surface (scored from 0 to 100) was multiplied by the barrier surface (scored from 0.2 to 0.8) to create the final existing semi-natural habitat connectivity surface.

6. Stage 3 – Modelling Habitat Opportunity Across the South Downs National Park

6.1 Introduction

6.1.1 The third stage of the project was to develop and apply habitat opportunity models to identify areas which are most suitable for the creation, connection and restoration of semi-natural habitats.

6.1.2 A key requirement was to build on the expertise developed during the development of the heathland, wetland and calcareous grassland habitat potential models by SxBRC for the SDNP:

- South Downs Wooded Heath Habitat Potential Model, November 2011;
- Adur & Ouse Catchment Habitat Potential Model (includes a range of wetland habitats), January 2012; and
- South Downs National Park Lowland Calcareous Grassland Habitat Potential Model, June 2012.

6.1.3 The priority habitats modelled by the SxBRC projects were:

- Lowland Calcareous Grassland;
- Lowland Dry Acid Grassland;
- Lowland Heathland;
- Coastal Saltmarsh;
- Lowland Meadows;
- Purple Moor-Grass and Rush Pastures;
- Coastal and Floodplain Grazing Marsh;
- Lowland Fens;
- Reedbeds;
- Wet Woodland; and
- Ponds.

6.1.4 The additional priority habitats modelled by this project are:

High Priority:

- Lowland Beech and Yew Woodland;
- Lowland Mixed Deciduous Woodland including Wood Pasture and Parkland and Traditional Orchards;
- Coastal Vegetated Shingle;
- Maritime Cliff and Slopes;
- Intertidal Chalk;
- Rivers;
- Arable Field Margins; and
- Hedgerows.

Low Priority:

- Intertidal Mudflats;
- Saline Lagoons; and

- Inland Rock Outcrop and Scree Habitats.

6.2 Application of the SxBRC Models to the Whole of the SDNP

6.2.1 The models created by SxBRC generally apply the same approach and have the following key features:

- Developed using ESRI ArcGIS software;
- Data was obtained from existing sources and no field collection or verification was undertaken;
- Grid-based with a 50 x 50m cell resolution;
- Employed a weighted overlay technique;
- A mechanistic and correlative approach was used and its limitations acknowledged;
- Four modelling stages were carried out:
  - Exclusion of areas with no potential;
  - Identification of all areas of habitat potential;
  - Identification of habitat specific potential areas; and
  - Prioritisation of habitat specific potential areas.
- Model parameters were reviewed and the most influential chosen including:
  - Size of potential habitat;
  - Proximity to same habitat type;
  - Proximity to other BAP habitat;
  - Presence of invasive species;
  - Designated sites;
  - Public accessibility; and
  - Indicator species
- Spatial relationships and connectivity analysis including Nearest Neighbour was undertaken for the output areas of habitat potential.

6.2.2 The ArcGIS toolboxes / models and accompanying reports were obtained from SxBRC and a discussion on their application was had with Henri Brocklebank and Andrew Lawson.

6.2.3 The input data layers and output habitat opportunity results were not made available for use on this project. This is a significant limitation to the project and required surrogate data layers to be sourced and manipulated to be suitable model inputs. It also meant that the validation and comparison between the two output datasets could not be made.

6.2.4 The ArcGIS models and reports were reviewed in combination with all available datasets, current best practice and our understanding of ecological opportunity modelling and the following observations made:

- The reports included introductory sections on each priority habitat type, distribution within the study area, habitat potential modelling and model development which are considered sufficient and therefore not repeated in this report;
- With the exception of the Lowland Calcareous Grassland model the models were developed and applied to much smaller study areas than the SDNP;
- The models took a largely vector based approach through the creation of a 50m polygon grid and the use of loops to select and calculate variable values which can be very computer intensive and time consuming;

- The reports provide an overview of the approach taken but omit a lot of detail with regards to the technical model development, inclusion of parameters and assignment of weights which make them easy to read but quite difficult to replicate with new or alternative data sources;
- There were discrepancies between the parameters specified in the report and those used in the models;
- The models were divided into 4 different stages which, in some cases, were not obviously linked or cohesive in terms of outputs from one becoming inputs to another;
- For some variables the models relied on specific, locally sourced data sets and knowledge which are not available across the whole of the SDNP at the required level of detail; and
- The models used a relatively simple weighting classification of High, Medium and Low for assessing the impact of a particular variable on potential habitat opportunity and there is limited justification or reasoning for their application.

6.2.5 To address and overcome the issues identified above new, updated models and datasets were created for each priority habitat type with the following features:

- An ArcGIS map document (*.mxd) was created to collate and symbolise each of the relevant layers and to allow spatial and attribute queries to interrogate the data further as required;
- A single geodatabase was created for each modelled habitat which contained all of the input and output datasets so that the model process can be tracked, repeated and results verified;
- A clear, consistent Microsoft excel spreadsheet was created detailing each of the model inputs, parameters and weighting factors;
- A wide ranging search was undertaken to source all available data layers to exactly match or provide a suitable surrogate to the SxBRC model inputs;
- A raster based approach was undertaken, with a cell size of 10m, as this is the most efficient method of managing continuous datasets across a large scale area such as the SDNP. The 10m resolution significantly improves the level of detail represented in the model and therefore should result in more accurate and reliable results;
- The vector layers were processed to assign the correct weighting factors to each polygon and then converted to raster grids for overlaying and analysis; and
- The simple weighting classification was maintained but it was quality checked and changed if necessary to compensate for changes in data layers or correct any errors.

6.2.6 The four step approach of excluding unsuitable areas, identifying overall potential areas, refining specific potential areas and finally prioritising potential areas was undertaken for each priority habitat type.

6.2.7 Table 6 shows the parameters included at each stage and identifies any modifications or differences to the original SxBRC models which may have had an impact on the final outputs.

6.2.8 The detail and justification for each model parameter and weighting factors are not included in this report but are contained within the accompanying ArcGIS Map Documents, Layers, Models and Excel spreadsheets.

Table 6 – Habitat Opportunity Modelling Parameters

Habitat Type	Stage 1 - Exclusion	Stages 2 and 3 - Overall and Specific Potential	Stage 4 - Prioritisation and Categorisation	Notes
Lowland Calcareous Grassland	Grade 1, 2 and 3 Agricultural Land Inland Water Urban Areas Railways 2.5m buffer Major Roads 10m buffer Minor Roads 5m buffer Urban Areas Landfill Existing Priority Habitats Schedule Ancient Monuments 5m Buffer Regionally Important Geological Sites	Chalk Bedrock Existing Land Cover / Use Slope Seedbank	Thomson Ecology Graph Theory Model Categorisation by nearest neighbours and size of potential semi-natural habitat	

Habitat Type	Stage 1 - Exclusion	Stages 2 and 3 - Overall and Specific Potential	Stage 4 - Prioritisation and Categorisation	Notes
Heathlands Lowland Dry Acid Grassland Lowland Heathland	Grade 1, 2 and 3 Agricultural Land Inland Water Urban Areas Railways 2.5m buffer Major Roads 10m buffer Minor Roads 5m buffer Urban Areas Landfill Existing Priority Habitats Schedule Ancient Monuments 5m Buffer Regionally Important Geological Sites	Soil Types Existing Land Cover / Use Priority Species Seedbank	Thomson Ecology Graph Theory Model Categorisation by nearest neighbours and size of potential semi-natural habitat	Historical Heathland Data for the whole of the SDNP was not available as an input to seedbank so proximity to existing heathland was used as an alternative.

Habitat Type	Stage 1 - Exclusion	Stages 2 and 3 - Overall and Specific Potential	Stage 4 - Prioritisation and Categorisation	Notes
Wetlands Coastal Saltmarsh Lowland Meadows Purple Moor-Grass and Rush Pasture Coastal and Floodplain Grazing Marsh Lowland Fens Reedbeds Wet Woodland	Railways 2.5m buffer Major Roads 10m buffer Minor Roads 5m buffer Urban Areas Landfill Made Ground Airport 13km buffer	Existing Land Cover / Use Soil Types Bedrock Geology EA Floodzone 2 Impeded Drainage Bedrock Geology Flood Risk from Surface Water Rivers Inland Water **Saltmarsh Only** Tidal Boundaries Littoral Sediment	Thomson Ecology Graph Theory Model Categorisation by nearest neighbours and size of potential semi-natural habitat	

Habitat Type	Stage 1 - Exclusion	Stages 2 and 3 - Overall and Specific Potential	Stage 4 - Prioritisation and Categorisation	Notes
Ponds	Urban Areas 30m Buffer Major Roads / Rail with 50m Upslope Buffer and 200m Downslope Buffer Landfill with 800m Downslope Buffer and 100m Buffer in all other directions Inland Water Existing Reedbeds, Fens, Saltmarsh, Mudflats and Wet Woodland Schedule Ancient Monuments 5m Buffer Arable Land	Slope of 0-5° Flood Risk from Surface Water Designated Sites RSPB Reserves Woodland Trust Sites Forestry Commission Sites	Invasive Species Presence Priority Species Diversity Proximity to Existing Wetland	Sussex Ponds Survey Data was not available

Habitat Type	Stage 1 - Exclusion	Stages 2 and 3 - Overall and Specific Potential	Stage 4 - Prioritisation and Categorisation	Notes
Lowland Mixed Deciduous Woodland	Grade 1, 2 and 3 Agricultural Land Inland Water Urban Areas Railways 2.5m buffer Major Roads 10m buffer Minor Roads 5m buffer Urban Areas Landfill Existing Priority Habitats Schedule Ancient Monuments 5m Buffer Regionally Important Geological Sites	Soil Types Existing Land Cover / Use Seedbank	Thomson Ecology Graph Theory Model Categorisation by nearest neighbours and size of potential semi-natural habitat	

Habitat Type	Stage 1 - Exclusion	Stages 2 and 3 - Overall and Specific Potential	Stage 4 - Prioritisation and Categorisation	Notes
Lowland Beech and Yew Woodland	Grade 1, 2 and 3 Agricultural Land Inland Water Urban Areas Railways 2.5m buffer Major Roads 10m buffer Minor Roads 5m buffer Urban Areas Landfill Existing Priority Habitats Schedule Ancient Monuments 5m Buffer Regionally Important Geological Sites	Soil Types Existing Land Cover / Use Priority Species Seedbank Slope Aspect	Thomson Ecology Graph Theory Model Categorisation by nearest neighbours and size of potential semi-natural habitat	

6.3 Prioritisation of the Habitat Opportunity Areas

6.3.1 The output of the habitat opportunity models was a continuous grid surface of values from 0 (no habitat potential) to 9 (high habitat potential) across the whole of the SDNP.

6.3.2 A threshold value of 6 and above was used to extract areas with the best and most realistic areas for habitat creation and restoration.

6.3.3 The raster was reclassified so that cells with a value of 6 or more were assigned a value of 1 and all other cells 0.

6.3.4 This raster was then converted to a polygon layer of potential habitat opportunity areas.

6.3.5 The potential habitat opportunity areas were scored and prioritised using the same methodology as the existing priority habitat parcels graph theory assessment completed in Stage 2.

6.4 Classification of Habitat Opportunity Types

6.4.1 The potential habitat parcels were, using their spatial relationship with existing priority habitat polygons of the same type, classified into different habitat opportunity types as specified in Table 7.

Table 7 – Classification of Habitat Opportunity Types

Habitat Opportunity Type	Description
Connector	Potential habitat polygon is adjacent (within 5m) of 2 or more existing priority habitat polygons
Extension (Potential<Existing)	Potential habitat polygon is adjacent (within 5m) of 1 larger existing priority habitat polygons
Extension (Potential>Existing)	Potential habitat polygon is adjacent (within 5m) of 1 smaller existing priority habitat polygons
Stepping Stone	Potential habitat polygon is within 100m of 2 or more existing priority habitat polygons
New Stand Alone Site	Potential habitat polygon is not within neighbour threshold distance and therefore considered a new standalone habitat parcel

6.5 Identifying Areas of Habitat Opportunity Conflict

6.5.1 The outputs from the habitat modelling exercise identified where the most appropriate areas within the SDNP are to create each priority habitat type.

6.5.2 The individual models were run in isolation and did not take into account the possibility of creating an alternative priority habitat in the same location, which given the similar requirements of some habitat types is highly likely, so it was important to identify areas of potential conflicting opportunity.

6.5.3 This was achieved by summing all of the priority habitat opportunity grids (0 or 1) together.

6.5.4 The output habitat conflict grid showed values of 1 for areas which are suitable for just one priority habitat type or >=2 for areas of multiple habitat suitability.

6.6 Development of Coastal Habitats Model

6.6.1 In addition to the terrestrial habitats described above, this project has an objective to map and model the following coastal habitats:

- Coastal Vegetated Shingle;
- Maritime Cliff and Slopes;
- Intertidal Chalk;
- Intertidal Mudflats; and
- Saline Lagoons.

6.6.2 Lake et al (2015) recognise that coastal habitats are naturally dynamic, constantly changing as tides, currents and storms erode or build shorelines. Many factors have played a part in creating the coastline that we see today: geology, glaciation, sea-level change, sediment supply, wind, wave, tide and human activities all play a role.

6.6.3 The SDNPA have identified that:

> *"Coastal and marine habitats make up a small but important part of the National Park and contain some of most diverse ranges of animals and plants. The health of these habitats is as important as any on the planet. The soft chalk coastline is changing relatively quickly. This creates special pressures on the animals and plants living there."*
>
> *"The marine habitats, because they are constantly being worn away, expose fossils that help us explore and understand the diversity of past life. Coastal cliffs, the shoreline and estuaries offer unique habitats that add to the diversity of present day plants and animals of the South Downs."*
>
> *http://learning.southdowns.gov.uk/wildlife-and-habitats/south-downs-habitats/coastal*

6.6.4 Figure 3 shows the distribution of coastal priority habitats within the SDNP which are restricted to the South East of the SDNPA where the boundary reaches the intertidal zone.

6.6.5 The total length of coastline is about 20km and nearly all of this is already classified as a priority habitat type (Coastal Vegetated Shingle, Maritime Cliff and Slope and Lowland Calcareous Grassland) which shows that, as described above, the habitats are already identified and valued.

6.6.6 The origins and development of the habitats to be modelled and suggested conservation actions are described in Table 8. Each of the habitats have evolved over thousands of years and are the result of a unique combination of environmental factors.

Table 8 – Coastal Priority Habitats (adapted from Lake et al, 2015)

Habitat	Origins and Development	Conservation
Coastal Vegetated Shingle	Most shingle systems in Britain and Ireland were formed by about 4000 years ago and have been naturally dynamic ever since. However, shingle communities are inherently fragile and easily damaged, and human pressures have substantially degraded and reduced the area of vegetated shingle.	Although most Coastal Vegetated Shingle is protected by conservation designations, its prospects are poor. Emphasis needs to be put on restoring the mobility of shingle systems and allowing the full successional stages to develop. This includes flood defence strategies and recreational pressure management.
Maritime Cliff and Slopes	Natural habitat created by the past and present erosion of rocks by wind and water. Very geology and topography dependent.	Lack of intervention is crucial to allow natural processes to continue and ensure a continuity of varied early-successional habitats. Buffer strips.
Intertidal Chalk	Natural habitat created by the erosion of chalk to result in the formation of vertical cliffs and gently sloping intertidal platforms. Habitat is rare as can only form in the right kind of geology. The area between Brighton and Eastbourne has considerable expanses of intertidal chalk.	Better coastal management and a reduction in large developments, pollution, disturbance and invasive non-native plants.
Intertidal Mudflats	Entirely natural habitat that forms as a result of waterborne particles settling on the sea or estuary bed. The underlying geology and topography of a coastline determines its basic shape and its potential accumulate and hold sediment.	Reduction of threats including pollution, dredging of source material, coastal squeeze, fishing, bait digging, commercial shellfish harvesting and recreational activities.
Saline Lagoons	Through natural geomorphological processes and as a consequence of the construction of sea defences.	Naturally transient features and habitat continuity can be a problem for some resident species if new lagoons are not formed. Threats include sea level rise, coastal development and pollution from agricultural run-off and sewage outlets.

6.6.7 We recommend that, due to the identification of existing coastal priority habitats, the small area available for coastal habitat creation, the specific habitat requirements and lack of available data representing these variables and the main conservation recommendation of reducing human impact and pressures on these habitats, the coastal habitats are mapped and considered on a case by case basis.

6.7 Development of a Rivers Model

6.7.1 Like coastal habitats, rivers are dynamic systems which have evolved through the combination of unique geological, topographic, climatic and geographic factors. They have the ability to continually rejuvenate and create new habitat although this can be limited by anthropogenic catchment management and flood defence.

6.7.2 The rivers and streams of the National Park create a range of wetland habitats that support a large number of different species. Indeed, the chalk streams of the National Park are very important for their biodiversity value – a recent survey by Nigel Holmes says that Sussex has some of the best examples of natural chalk stream habitats in the country.

6.7.3 In addition, adjacent semi-natural wetland habitats such as unimproved floodplain grasslands, marshy grassland, wet heath, fens, bogs, flushes, swamps and wet woodland are intimately linked with the river to create complex semi-natural habitat mosaics.

6.7.4 Importantly to this project, rivers and streams often provide a wildlife corridor link between fragmented habitats in intensively farmed areas.

6.7.5 The main rivers in the National Park are the Itchen, Rother, Meon, Arun, Ouse, Cuckmere, and Adur and they are shown in Figure 4.

6.7.6 The nature and location of rivers and streams dictates that it is not possible or plausible to design a model to identify opportunities for habitat creation for these priority habitats.

6.7.7 We, therefore, recommend that a definitive rivers dataset is created which can be used in conjunction with the other semi-natural habitat connectivity and opportunity layers. The rivers can be viewed, queried and buffered as required.

6.7.8 The rivers dataset was created by performing a spatial selection of OS Mastermap Water polygons which intersect the Environment Agency WFD River Waterbodies Cycle 2 layer.

6.8 Development of Hedgerows and Arable Field Margins Model

6.8.1 The SDNPA Partnership Management Plan states that nearly 85 per cent of land within the National Park is classified as agricultural with nearly half of this is arable crops.

6.8.2 There is no existing dataset of either hedgerows or arable field margins covering the whole of the SDNP and the creation of one is beyond the scope of this project. However, both habitats can occur in similar locations, are a similar shape and size and have the potential to provide significant improvements in habitat connectivity across the SDNP.

6.8.3 A methodology was therefore developed to identify areas where hedgerows and arable field margins could, and possibly already are, making a contribution to habitat connectivity in the SDNP.

6.8.4 The model focussed on existing arable land and this was extracted from the BAP Broad Habitat layer as the primary data input to this model.

6.8.5 The polygons were processed in ArcGIS to extract the arable field boundaries as lines which were then buffered by 10m to represent a hedgerow and or arable field margin.

6.8.6 The output of this model is a polygon layer of existing or potential hedgerows and field margins within arable land.

6.8.7 It is appreciated that this is a very basic approach and has the following limitations:

- Assumes that all arable fields have or can have a hedgerow and or a field margin as their boundary;
- Makes no consideration or assessment of hedgerow or field margin quality; and
- Does not take into account current agriculture land use, crop type and any management / stewardship schemes.

6.8.8 However, the layer can be combined, overlaid and queried with existing and potential semi-natural habitat to identify where areas good quality, intact, species rich hedgerows and field margins could add significant ecological value across the SDNP.

6.8.9 The layer also provides an excellent starting point for the development of a better, more complete and quality assured hedgerow and field margin dataset.

6.9 Mapping Existing Connectivity with Proposed Opportunity

6.9.1 The final stage of the project took the outputs of Stages 2 and 3 and overlaid them to compare and contrast areas of existing semi-natural habitat connectivity with potential habitat opportunity to restore an ecological functional network or semi-natural habitats across the SDNP.

7. Results

7.1 Introduction

7.1.1 The primary outputs of this project are the ArcGIS map documents, data layers and models which are delivered as accompaniments to this report which can be analysed and interpreted in a wide variety of ways for differing purposes.

7.1.2 This results section will present a summary of the main findings for each habitat for each stage of the model.

7.1.3 The results for each habitat type should be interpreted individually and carefully with consideration for both the habitat type and the South Downs National Park. Many of the priority habitat types are uncommon in the SDNP with only a few parcels / small total area and therefore cannot be successfully mapped and modelled to draw meaningful conclusions. Priority habitats which make up less than 1% of the total priority habitat area are:

- Coastal saltmarsh
- Coastal vegetated shingle
- Lowland dry acid grassland
- Lowland fens
- Lowland meadows
- Maritime cliff and slope
- Mudflats
- Purple moor grass and rush pastures
- Reedbeds
- Saline lagoons
- Traditional orchard

7.1.4 The delivered ArcGIS files will allow more detailed and specific outputs to be quickly and easily created.

7.2 Distribution of Existing Semi-Natural Habitat

7.2.1 Figure 5a to 5q show the distribution of each semi-natural (priority) habitat across the SDNP. Each habitat is symbolised by a graduated colour scale from dark where the habitat occurs to light showing areas of deficiency.

7.2.2 Table 9 and Graph 1 show Priority Habitats present within the SDNP with a count of Ordnance Survey polygons, derived habitat parcel count and total area in hectares.

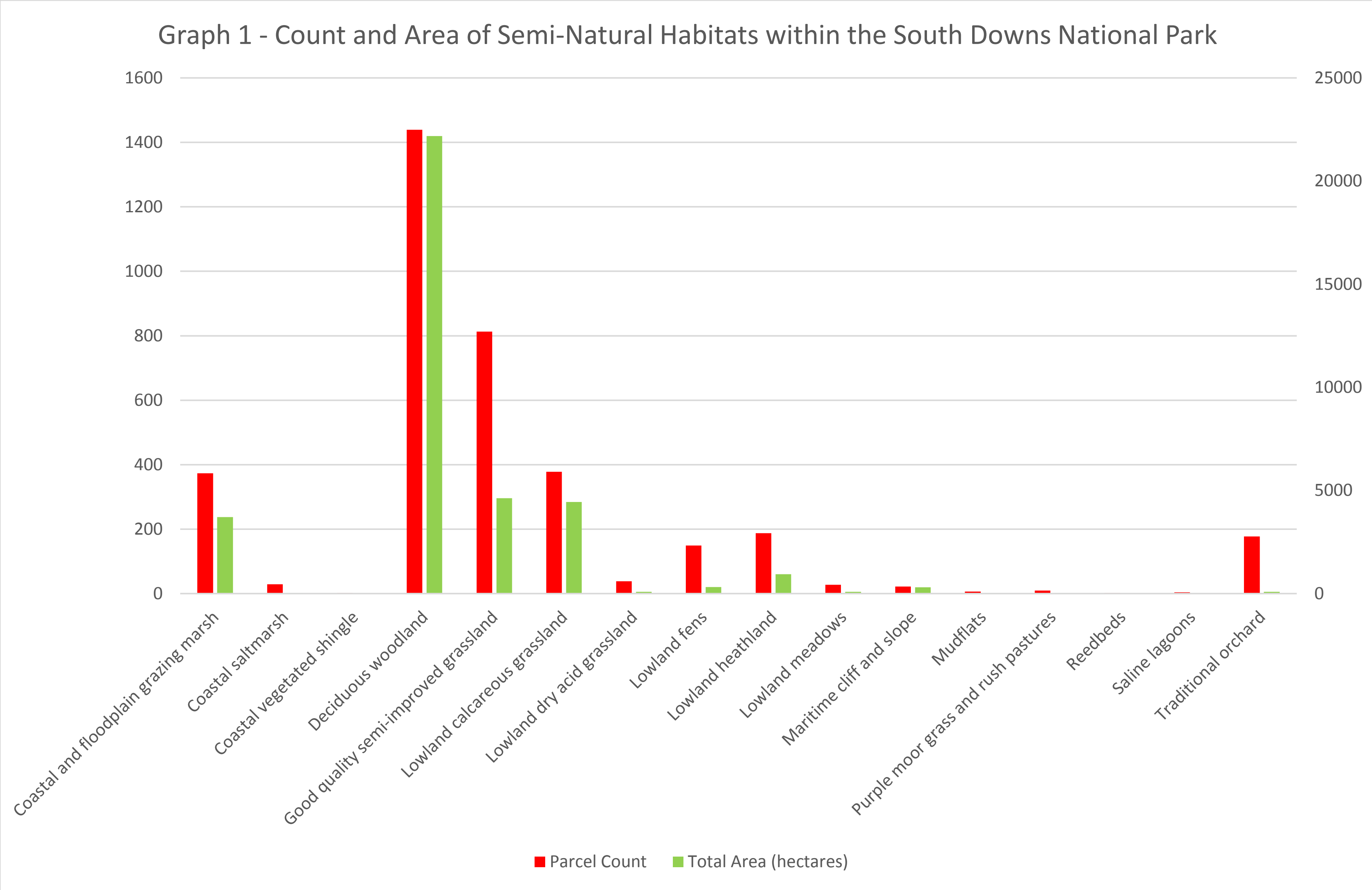
7.2.3 Table 9 includes a column for initial observations and comments as a starting point for further investigation, analysis and discussion.

Table 9 - Priority Habitats present within the SDNP with a polygon count, parcel count, total area in hectares and comments / observations on their distribution.

Priority Habitat	Polygon Count	Parcel Count	Total Area (hectares)	Proportion of SDNP Priority Habitat Area (%)	Observations and Comments
Coastal and floodplain grazing marsh	1134	373	3709	10.07	The fourth most widespread habitat in the SDNP but, as would be expected, restricted to the major river valleys of the Cuckmere, Ouse, Adur, Arun, Rother, Meon and Itchen. High parcel to area ratio could indicate susceptible to habitat fragmentation.
Coastal saltmarsh	85	29	21	0.06	Low number and area of priority habitat which is restricted to the coastal / estuarine rivers of the Cuckmere, Arun, Adur and Ouse in the south and south east of the SDNP.
Coastal vegetated shingle	3	2	7	0.02	Very low number and area of priority habitat which is restricted to the coastal boundary in the south east of the SDNP.
Deciduous woodland	13466	1439	22190	60.24	The most widespread and extensive priority habitat across the SDNP accounting for over half of the total – particularly dominant in central and western areas but more sparse and restricted in the east.
Good quality semi-improved grassland	1593	813	4625	12.55	The second most abundant priority habitat within the SDNP and with a relatively even distribution across the whole of the study area although less frequent in the north and west. Dense patches of parcels in some areas. High parcel to area ratio could indicate susceptible to habitat fragmentation.

Priority Habitat	Polygon Count	Parcel Count	Total Area (hectares)	Proportion of SDNP Priority Habitat Area (%)	Observations and Comments
Lowland calcareous grassland	1590	378	4436	12.04	The third most abundant priority habitat within the SDNP and its distribution is almost entirely restricted to the southern half of the study area with concentrations highest in the east.
Lowland dry acid grassland	51	38	84	0.23	Low number of parcels and total area of priority habitat which is found almost exclusively in the central north of the SDNP with a concentration around the town of Liss.
Lowland fens	556	149	311	0.84	Medium number of habitat parcels but a low total area indicates small individual habitat size. Localised distribution within the SDNP with concentrations in the Arun, Itchen and Wey Valleys.
Lowland heathland	619	187	935	2.54	Moderate number of parcels and total area almost exclusively distributed in the central north of the SDNP with very isolated parcels outside this area.
Lowland meadows	58	27	78	0.21	Low number and area of priority habitat which are distributed in isolated patches towards the northern, southern and western boundaries of the SDNP.
Maritime cliff and slope	171	22	302	0.82	Low number of parcels and, as would be expected, localised to the coastal boundary in the south east of the SDNP.
Mudflats	13	6	20	0.06	Only 6 habitat parcels - long, linear habitats along the river channels of the Cuckmere, Arun, Adur and Ouse.

Priority Habitat	Polygon Count	Parcel Count	Total Area (hectares)	Proportion of SDNP Priority Habitat Area (%)	Observations and Comments
Purple moor grass and rush pastures	20	9	26	0.07	Low number and total area of priority habitat which are distributed in isolated patches towards the northern, southern and western boundaries of the SDNP.
Reedbeds	8	2	4	0.01	Only 2 parcels of priority habitat – one at the Wildfowl and Wetland Trust, Arundel and the other near South Dole.
Saline lagoons	4	4	11	0.03	Very low number and area of priority habitat which is restricted to the coastal boundary in the south east of the SDNP.
Traditional orchard	198	177	79	0.22	Relatively high number of habitat parcels and evenly distributed across the SDNP but low total area due to size and nature of managed habitat type.


Graph 1 - Count and Area of Semi-Natural Habitats within the South Downs National Park
1600
1400
1200
1000
800
600
400
200
0
25000
20000
15000
10000
5000
0
Coastal and floodplain grazing marsh
Coastal saltmarsh
Coastal vegetated shingle
Deciduous woodland
Good quality semi-improved grassland
Lowland calcareous grassland
Lowland dry acid grassland
Lowland fens
Lowland heathland
Lowland meadows
Maritime cliff and slope
Mudflats
Purple moor grass and rush pastures
Reedbeds
Saline lagoons
Traditional orchard
Parcel Count
Total Area (hectares)

7.3 Quality of Existing Semi-Natural Habitat

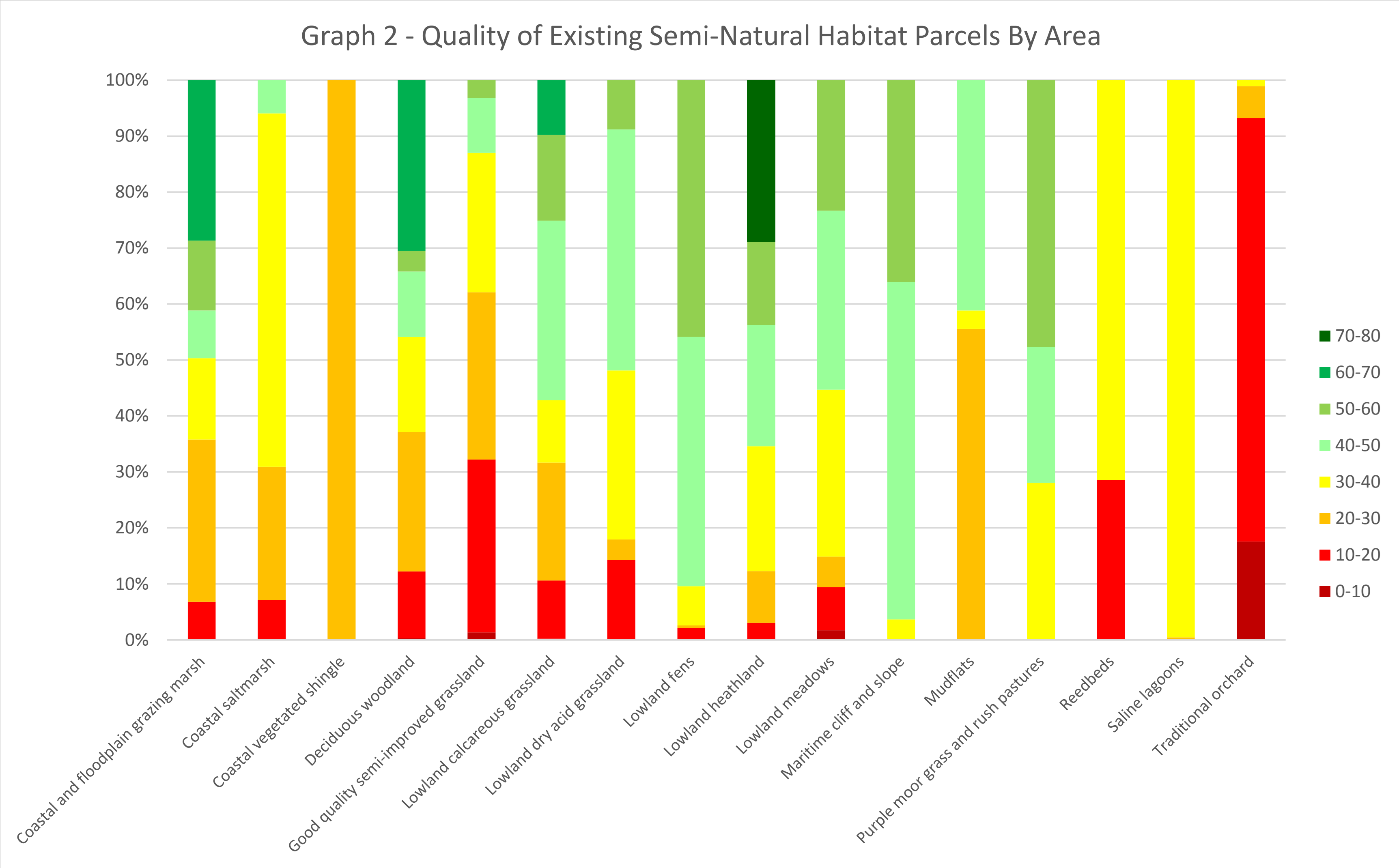
7.3.1 Figure 6a to 6q show the quality of each semi-natural (priority) habitat across the SDNP. Each habitat is symbolised by a graduated colour scale from dark, showing areas of high quality habitat parcels, to light, showing areas with lower quality habitat parcels.

7.3.2 The colour symbology is restricted to a 1km buffer around each priority habitat parcel.

7.3.3 The maps need to be interpreted with care as the variable modelled is the existing habitat parcel quality score and therefore the interpolated values across the SDNP vary considerably and inconsistently depending on the quality score and relative, localised distribution of habitat parcels.

7.3.4 The maps can and are designed to be used as guidance and were an important stage in the model development.

7.3.5 Graph 2 illustrates the quality score distribution for each priority habitat type by total area.


Graph 2 - Quality of Existing Semi-Natural Habitat Parcels By Area
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Coastal and floodplain grazing marsh
Coastal saltmarsh
Coastal vegetated shingle
Deciduous woodland
Good quality semi-improved grassland
Lowland calcareous grassland
Lowland dry acid grassland
Lowland fens
Lowland heathland
Lowland meadows
Maritime cliff and slope
Mudflats
Purple moor grass and rush pastures
Reedbeds
Saline lagoons
Traditional orchard
70-80
60-70
50-60
40-50
30-40
20-30
10-20
0-10

7.4 Barriers to Existing Semi-Natural Habitat Connectivity

7.4.1 Figure 7 and Table 10 show the barriers to existing semi-natural habitat connectivity within the SDNP.

Table 10 - Barriers to Existing Semi-Natural Habitat Connectivity

Barrier	Total Area (Ha)
Intensive Agriculture	82057
Urban Areas	8539
Major Roads	572
Minor Roads	1178
Rivers	620
Landscape Character Boundaries	261
Total	**93227**

7.4.2 The total area of all barriers is 93227 hectares which is 56% of the total land area of the SDNP of 165267 hectares.

7.5 Existing Semi-Natural Habitat Connectivity

7.5.1 Figure 8a to 8p show the existing semi-natural habitat connectivity for all priority habitats which occur within the SDNP.

7.5.2 They are coloured from green, showing areas of relatively high connectivity for that habitat type, to red, showing areas of low connectivity.

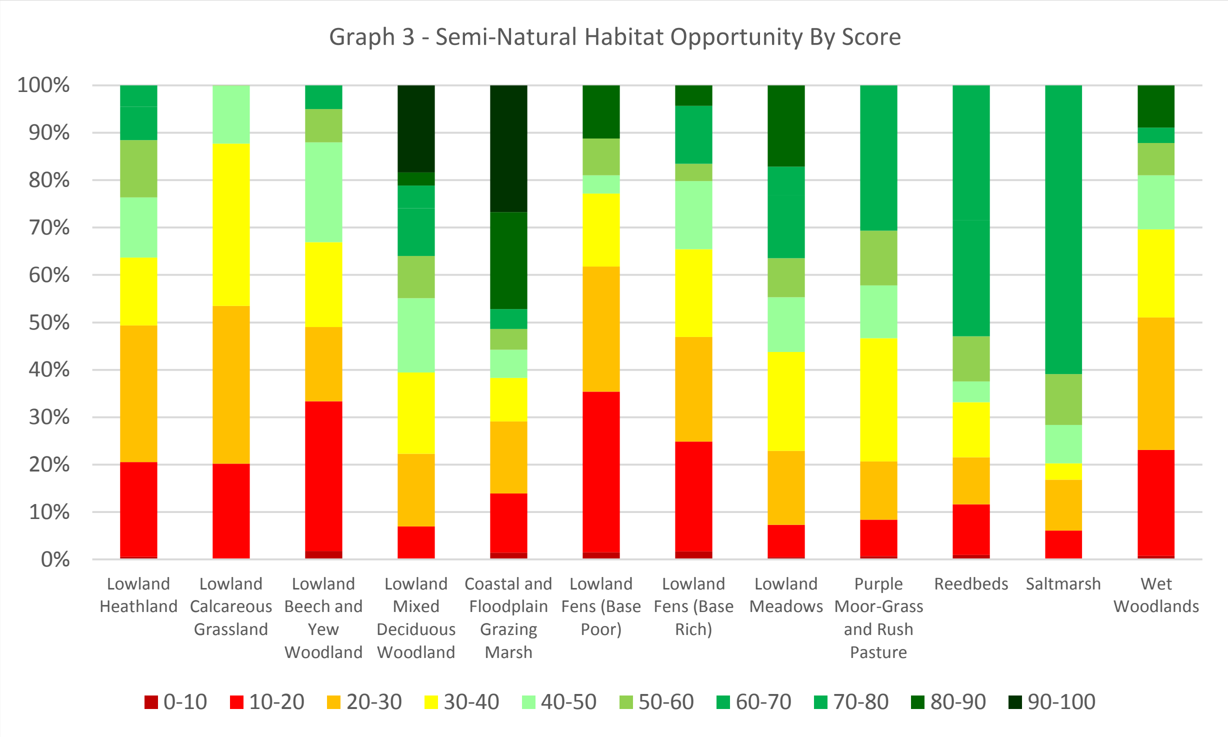
7.5.3 The colour symbology is restricted to a 1km buffer around each priority habitat parcel.

7.6 Semi-Natural Habitat Opportunity By Score

7.6.1 Figure 9a to 9n show the Semi-Natural Habitat Opportunity by Score for each of the modelled habitats.

7.6.2 They are coloured from red, showing low scoring areas, to green showing high scoring areas, and therefore most suitable for creation of that habitat.

7.6.3 Graph 3 shows the breakdown of the opportunity scores for each habitat type and, as an example, can be interpreted to see that Lowland Mixed Deciduous Woodland and Coastal and Floodplain Grazing Marsh have the potential to create the highest quality habitat.



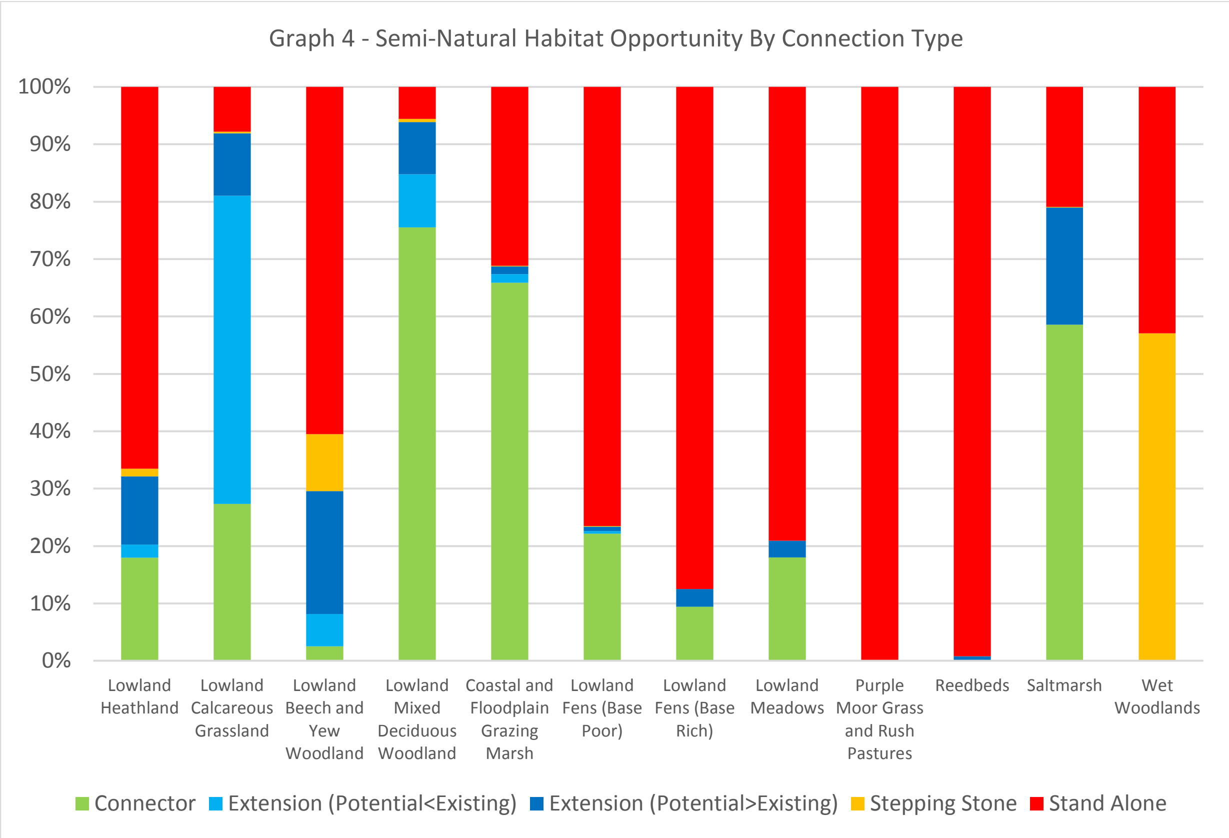
7.7 Semi-Natural Habitat Opportunity By Connection Type

7.7.1 Figure 10a to 10n show the Semi-Natural Habitat Opportunity by Connection Type for each of the modelled habitats.

7.7.2 Each of the maps can be used to see where the most appropriate intervention can be made to make the best possible improvement in semi-natural habitat connectivity.

7.7.3 Graph 4 shows the breakdown of the opportunity scores for each habitat type.

7.7.4 As an example it can be seen that the two predominant connection types are connector and stand alone sites.



7.8 Semi-Natural Habitat Opportunity Conflicts

7.8.1 Figure 11 and Table 11 show the semi-natural habitat opportunity conflict within the SDNP.

7.8.2 Opportunity areas are coloured from dark green, where there is the potential for 2 habitats, to dark red, where there is the potential for 10 different habitats.

Table 11 - Semi-natural habitat opportunity conflict within the SDNP

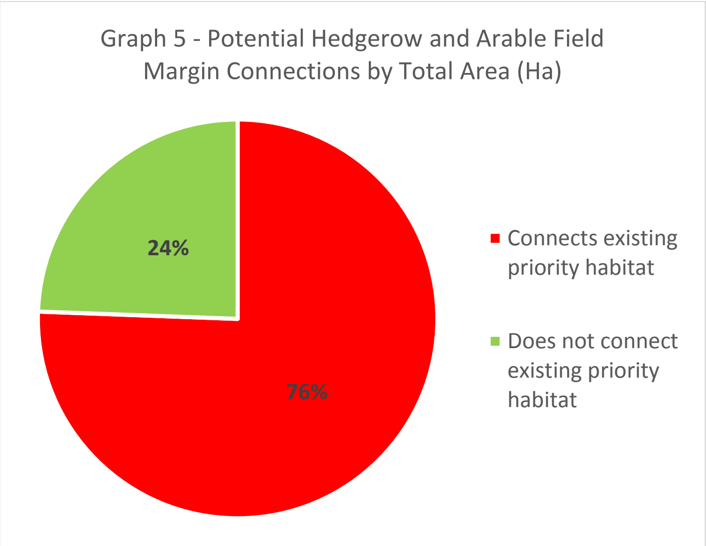
Number of potential habitats	Count of parcels	Total Area (Ha)
2	24220	16519
3	13258	3044
4	8300	2392
5	6267	1708
6	4514	2002
7	3088	953
8	1527	353
9	457	85
10	63	2

7.9 Hedgerows and Arable Field Margins

7.9.1 Figure 12 shows the distribution of the derived hedgerows and arable field margins with those neighbouring and connecting priority habitat parcels in red and those not connected in green.

7.9.2 Graph 5 shows the percentages of potential hedgerow and arable field margin connections by total area, assuming a 10m hedgerow / field margin width.

7.9.3 This highlights that hedgerows and arable field margins could play a significant role in semi-natural habitat connectivity across the SDNP.



8. References

8.1.1 Partnership Management Plan - shaping the future of your South Downs National Park, 2014-2019. South Downs National Park Authority, 2013.

8.1.2 Lawton J (2010) Making Space for Nature: A review of England's Wildlife Sites and Ecological Network. Report to DEFRA.

8.1.3 Department for Environment, Food & Rural Affairs (2011) The Natural Environment White Paper: implementation updates.

8.1.4 Department for Communities and Local Government (2012) National Planning Policy Framework.

8.1.5 Department for Communities and Local Government (2014) National Planning Practice Guidance.

8.1.6 Forest Research & Centre for Ecology and Hydrology (2008) Habitat Connectivity – Developing an indicator for UK and country level reporting. Phase 1 Pilot Study. Final report for DEFRA Research Contract CR0388.

8.1.7 Catchpole RDJ (2006) Planning for Biodiversity – opportunity mapping and habitat networks in practice: a technical guide. English Nature Research Reports, No 687.

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

8.1.9 Briers R (2011) Habitat networks – reviewing the evidence base: Final Report. Contract Report to Scottish Natural Heritage, contract number 29752.

8.1.10 Briers, R (2011?) Habitat networks: from principles to best practice. Guidance on the interpretation and use of habitat network models. Scottish Natural Heritage.

8.1.11 Latham J & Gillespie J (2009) Applying connectivity mapping to spatial planning in Wales. Proceedings of the Sixteenth Annual IALE (UK) Conference.

8.1.12 Watts, Kevin; Handley, Philip; Scholefield, Paul. (2008) Developing a habitat connectivity indicator for the UK: examining potential change in model landscapes. In: Landscape Ecology and Conservation. Proceedings of the fifteenth annual IALE(UK) conference, Murray Edwards College, Cambridge, 8-10 September 2008. (Unpublished)

8.1.13 Fischer, Joern and Lindenmayer, David B. (2007) Landscape modification and habitat fragmentation: a synthesis. Global Ecology and Biogeography, 16,265-280.

8.1.14 Donald, Paul F. and Evans, Andy D. (2006) Habitat connectivity and matrix restoration: the wider implications of agri-environment schemes. Journal of Applied Ecology, 43, 209-218.

8.1.15 Medcalf, Katie and Turton, Nicki (2012) Mapping landscape permeability within the Frome and Piddle catchments to prioritise areas for targeted habitat creation and protection. Environment Systems Ltd.

8.1.16 Minor, Emily and Urban, Steve (2007) Graph theory as a proxy for spatially explicit population models in conservation planning. Ecological Applications 17(6) 1771 -1782. Ecological Society of America.

8.1.17 McRae BH, Hall SA, Beier P, Theobald DM (2012) Where to Restore Ecological Connectivity? Detecting Barriers and Quantifying Restoration Benefits. PLoS ONE 7(12): e52604. doi:10.1371/journal.pone.0052604

8.1.18 Lake S, Liley D, Still R and Swash A (2015) Britain's Habitats – A guide to the wildlife habitats of Britiain and Ireland. Princeton University Press.