Definition of Favourable Conservation Status for hedgerows

Defining Favourable Conservation Status Project

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Executive summary

This document sets out Natural England's view on favourable conservation status for hedgerows in England.

Favourable conservation status is the minimum threshold at which we can be confident that the habitat, and its associated species, are thriving in England and are expected to continue to thrive sustainably in the future.

This definition has been produced following the Natural England approach to defining favourable conservation status described in the guidance document Defining Favourable Conservation Status in England.

Section 1 of this document describes the habitat covered by this definition and its ecosystem context.

Section 2 specifies the units used to describe the three favourable conservation status parameters. These are:

- Natural range and distribution (where the habitat occurs).
- Extent (how much habitat there is).
- The structure and function attributes (habitat quality).

Section 3 outlines the evidence considered when developing the definition. This definition is based on the best available evidence on the ecology of hedgerows. The evidence covers the current situation, historical changes and possible future changes.

Section 4 sets out the conclusions on the favourable values, which is the value for each of the three parameters when the habitat has achieved favourable conservation status.

This document does not include any action planning, or describe actions, to achieve or maintain favourable conservation status. These will be presented separately, for example within strategy documents.

Summary definition of favourable conservation status

Hedgerows are a widespread Priority Habitat (that is, a habitat of principal importance for biodiversity conservation), providing key semi-natural habitat for a broad range of biodiversity, including many threatened species. They occur predominantly in lowland farmland but also in urban areas. The distribution of hedgerows reflects historic and current agricultural and social practices and underlying biophysical variables. Hedgerows are largely man-made features, which historically were created through the planting of woody species for the specific purpose of dividing up rural land and preventing the movement of stock between land parcels. In urban areas, hedgerows have mainly been planted to create boundaries between properties, for aesthetic or wildlife reasons within gardens and parks.

The length of hedgerows in England needs to increase substantially in order to support thriving biodiversity and to achieve Favourable Conservation Status (FCS). There is a moderate amount of evidence supporting the recommended level of increase in hedgerow, but the evidence that is available overwhelmingly supports an increase in length for a range of taxa. Overall confidence in an increase in hedgerow length being required is high.

Higher average density of hedgerows (in suitable habitats) due to increased length will result in improvements in the provision of hedgerow habitat for wildlife and in landscape connectivity. The use of hedgerows by mobile species for daily movement (for example, foraging) is well supported by available evidence, across a range of taxa. There is less evidence for the role of hedgerows for population dispersal or migration, despite their strong potential to support connectivity and the likely importance of this in the context of climate change.

Since hedgerows consist primarily of shrubs and trees, their distribution is associated with that of shrubby and/or woodland habitats. There is strong evidence that to achieve Favourable Conservation Status the national distribution of hedgerows is likely to remain broadly unchanged. However, increases in extent will alter the smaller scale distribution of hedgerows in parts of the current range. Evidence about the specific types of landscapes in which additional hedgerows may best be placed to optimise support to biodiversity is limited.

The quality of hedgerows, defined through a series of structural and functional attributes, strongly determines how well hedgerows support biodiversity across a broad range of taxa. Hedgerow height and width, the provision of flowers (pollen and nectar resources for pollinators) and berries (for overwintering wildlife), the presence of mature trees, and the density and structural diversity of the hedgerow network are all examples of quality attributes which affect how well hedgerows can support wildlife. Detailed recommendations and thresholds for these quality attributes are given in this document, based both on current hedgerow condition criteria and additional attributes for which good evidence is available. Overall, the evidence for the requirement that hedgerows need to be of good quality (as defined here) to support thriving biodiversity is strong. Currently, the majority of hedgerows in England are not in good condition, which poses a considerable threat to achieving FCS for hedgerows.

Table 1 Confidence levels for the favourable values

Favourable conservation status parameter	Favourable value	Confidence in the proposed favourable value
Range and distribution	Maintenance of the current range nationally, but an increase in the smaller scale distribution of hedgerows within some parts of the range, due to the required increase in extent.	High

Favourable conservation status parameter	Favourable value	Confidence in the proposed favourable value
Extent	An extra 335,000 km length of rural hedgerow is required to achieve FCS, which would bring the total hedgerow length in England to around 882,000 km. This is equivalent to an average density (used here as a proxy for connectivity) of 10 km / km^2 in habitats suitable for hedgerow. It is a 61% increase in the current rural hedgerow length in England of 547,000 km (current density approximately 4.52 km / km^2 in relevant habitats). One hedgerow standard tree is required every 40 m of hedgerow length to achieve FCS. This is equivalent to 22 million trees and is a 14-fold increase in the current estimate of 1.6 million hedgerow tree numbers.	High
Quality (structure and function)	The low proportion of English hedgerows in good structural condition is a serious threat to the hedgerow habitat reaching FCS. To achieve FCS, 95% of the hedgerow habitat must meet the structural and functional requirements for a good quality habitat to support thriving biodiversity.	High

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About the Defining Favourable Conservation Status project

Natural England’s Defining Favourable Conservation Status (DFCS) project is defining the minimum threshold at which habitats and species in England can be considered to be thriving. Our Favourable Conservation Status (FCS) definitions are based on ecological evidence and the expertise of specialists.

Through setting our ambition and aspiration for species and habitats, our definitions will inform decision making and actions to achieve and sustain thriving wildlife.

Our FCS definitions will be embedded into delivery of the 25 Year Environment Plan, through the Nature Recovery Network, biodiversity net gain and environmental land management schemes (ELMS).

Conservation bodies will use them to inform their work, including management planning for the land they own. Businesses will have a clear understanding of how their work impacts nature recovery and how they can help contribute to achieving thriving nature.

By considering the evidence for FCS, decisions will be more confident and strategic, with an understanding of their contribution to, or impact on, the national ambition.

1. Habitat definition and ecosystem context

1.1 Habitat definition

The definition of a hedgerow used in this definition is “Any boundary line of trees and/or shrubs over 20 m long and less than 5 m wide, where any gaps between the trees or shrub species are less than 20 m wide, and where England native woody species form 80% or more of the cover. Any bank, wall, ditch or tree within 2 m of the centre of the hedgerow is considered to be part of the hedgerow, as is the herbaceous vegetation within 2m of the centre of the hedgerow”. This is in line with the priority habitat definition developed by Steering Group for the UK Biodiversity Action Plan for Hedgerows (now Hedgelink) and used by the JNCC for the UK Priority Habitat (Maddock 2008). It is also in line with the Defra definition used for Countryside Stewardship.

The definition includes hedgerows in all states of growth, whether recently planted, layed or coppiced, or grown into lines of mature trees/shrubs, and all states in between. It includes any standard trees that may be within a hedgerow, and the soils beneath the hedge.

Both rural and urban hedgerows are included within this FCS definition. Thus, hedgerows within and around gardens, for example, are covered where they meet the definition.

The priority habitat excludes patches of scrub, belts of trees or scrub greater than 5 m wide and banks or walls without woody shrubs on top of them (Maddock 2008). Therefore, many Cornish ‘hedges’, for example, which are earth banks often lacking woody growth, are excluded.

Headlands or field margins beyond 2 m from the centreline of the hedgerow are also not considered to be part of the hedgerow definition.

A list of woody species native to England (and Wales) can be found in the Hedgerows Regulations 1997 (Schedule 3). This information can also be found in the Hedgerow Survey Handbook (Defra 2007, Appendix 11). Bramble, honeysuckle and some other climbers and ramblers are not included in these lists and as a consequence boundary features that are composed solely of these species do not fall within the FCS hedgerow definition.

No distinction is made between the terms hedge and hedgerow – the two terms are commonly used interchangeably.

Differences from other definitions

The definition of a hedgerow in the Hedgerow Survey Handbook (Defra 2007) is: “A hedgerow is defined as any boundary line of trees or shrubs over 20 m long and less than

5 m wide at the base, provided that at one time the trees and shrubs were more or less continuous. It includes an earth bank or wall only where such a feature occurs in association with a line of trees or shrubs. This includes 'classic' shrubby hedgerows, lines of trees, shrubby hedgerows with trees and very gappy hedgerows (where each shrubby section may be less than 20 m long, but the gaps are less than 20 m)". This definition is wider than that given for the Priority Habitat in as much as it includes hedgerows with less than 80% cover of woody native species. This is in line with the definition used for The Biodiversity Metric 2.0, designed to help developers and land managers to better understand and quantify the current value of a place for nature (Crosher and others 2019a).

The term hedgerow is not defined in the Hedgerows Regulations 1997. Under such circumstances it is usual, under law, to use the Oxford English Dictionary definition. Here a hedgerow is said to be "A row of bushes forming a hedge, with the trees, etc. growing in it; a line of hedge", and a hedge "A row of bushes or low trees (for example, hawthorn, or privet) planted closely to form a boundary between pieces of land or at the sides of a road: the usual form of fence in England". Garden hedges are excluded from the Hedgerow Regulation definition of hedgerows.

The range of variation within English hedgerows

Hedgerows, even those predominantly of native species, are very varied in terms of age, structure and species composition, both within and between different English regions.

Hedgerows have three main origins – they have either (a) developed through natural regeneration along fence lines, ditches or banks, (b) been planted, or (c) are remnants (or ghosts) of woodlands that have been grubbed out (Rackham 1986). The great majority of hedgerows in England have been planted. Much of the ecological variation within hedgerows arises from the method of formation and from their age. For example, based on research in Devon, Lincolnshire, Cambridgeshire, Huntingdonshire and Northants, Max Hooper found that hedgerows, on average, gain one woody species roughly every 100 years, per 30 metre length (Pollard and others 1974).

The majority of the hedgerows in south-west England have high banks while hedgerows across the rest of the country are largely unbanked or have low banks. Hedgerows vary considerably in their width and height, according to the region in which they occur, their stage of growth, and management. Drainage ditches may run alongside hedgerows (banked or otherwise). The presence or absence of both banks and ditches has a considerable influence on hedgerow biodiversity.

The woody species composition of hedgerows reflects their geographic location, their age, and the species they were originally planted with, or for woodland relic hedges the species making up the original woodland. Using data from Countryside Survey (a randomly stratified sample-based survey of GB based on field data collection), French and Cummins (2001) identified eleven classes of hedgerow based on their woody growth. The hedgerows within nearly half (46%) of plots examined were dominated by hawthorn, and blackthorn was the main species in a further fifth (22%). The remaining hedgerows were either more species-rich (mixed hazel *Corylus avellana* and rich-hawthorn *Crataegus* spp, - 18%) or dominated by beech *Fagus sylvatica*, elder *Sambucus nigra*, willow *Salix* spp., elm *Ulmus* spp. or gorse *Ulex europaeus* (10%; figures derived from Table 1 in French and Cummins 2001).

Hedge-bottom flora was more evenly grouped by French and Cummins (2001) into four classes whose species composition could be related to broad land use/habitat types: intensive arable, rotational/mixed farming, managed grasslands, and woodland. Woody species diversity, and diversity of hedge bottom flora were not strongly related to one another leading to the conclusion that woody growth and hedge bottom flora should be considered ecologically as largely independent units. This reflects the fact that the hedge herbaceous flora is rarely planted and typically reflects surrounding land use and management intensity, both currently and historically. For example, those next to ungrazed grasslands or arable fields may be dominated by tussocky grasses, while those next to fields that receive high levels of fertilizer input are often dominated by nettles (*Urtica dioica*) or goosegrass (*Galium aparine*). Occasionally, hedge bottom floras are remnants of former species-rich grassland (Wilson 2019). In other instances, the flora is rich in herbs that include ancient woodland indicators (Garbutt & Sparks 2002), as with many lane-side ancient Devon banked hedges (Devon County Council & The Devon Hedge Group 1997). There is evidence the number of woodland indicator species in some hedgerows is reducing (Smart and others 2001; Garbutt & Sparks 2002).

Critchley and others (2013), using more recent Countryside Survey data, developed an alternative, functional, classification of herbaceous hedgerow flora, to guide restoration work. Thirteen different vegetation types in six broad groups were identified. The broad groups were woodland herbs, species-rich or semi-improved grassland, rank grassy vegetation, species-poor pasture, disturbed arable and sparse vegetation.

Mature or semi-mature trees are a frequent component of hedgerows, sometimes present as lines of trees or shrubs (where hedgerows have been allowed to grow unchecked), sometimes as standard trees where the trees have been specifically planted or selected by land managers to be allowed to develop to maturity and develop full, open-grown crowns over a managed hedge. Ash and oak are the most frequent hedgerow trees in England and Wales, although locally sycamore, beech, field maple, hawthorn and willows can predominate (Barr and others 1999).

Wilson (2019) lists the principal woodland and scrub NVC communities associated with hedgerows in Britain as W1 (grey willow - marsh bedstraw woodland), W8 (a, d, e) (ash - field maple - dog's mercury woodland), W10 (a, c) (oak - bracken - bramble woodland), W14/W15 (beech - bramble and beech - wavy hair-grass woodlands) , W21 (b/c, d) (hawthorn - ivy scrub) , W22 (blackthorn - bramble scrub), W23 (common gorse - bramble scrub) and W24 (bramble - Yorkshire fog underscrub).

Wilson (2019) also gives some NVC grassland communities associated with hedge bases. MG1 (a, b, c, d, e) (false oat-grass grasslands) is typical of ungrazed situations such as road verges, tracksides and arable field margins. In northern England, MG3 (a, c) (sweet vernal-grass - wood cranesbill grassland) can occur, as remnants of upland hay meadows, while hedgerows near west-facing coasts can include fragments of MC9 (red fescue - Yorkshire fog grassland), MC12 (red fescue - bluebell maritime bluebell community, and H8c (heather - western gorse heath).

1.2 Habitat status

Hedgerows are listed as a habitat of principal importance for biodiversity conservation under Section 41 of the Natural Environment and Rural Communities (NERC) Act 2006 (England). This reflects their previous listing as a Priority Habitat within the UK Biodiversity Action Plan (revised 2007 JNCC).

Hedgerows support numerous Section 41 species alongside other species of conservation concern. These are covered in Section 3.1 below. As an example of their high importance for biodiversity, over 21 Section 41 bird species are associated with hedgerows and for 13 of these, hedgerows are a primary habitat (Countryside Survey 2009). Similarly, as many as 16 out of the 19 birds used by Government to assess the state of farmland wildlife are associated with hedgerows, with ten using them as a primary habitat.

Hedgerows are not listed under Annex 1 of the EU Habitats and Species Directive as a Priority Habitat. However, the directive requires, under Article 10, that “Member States shall endeavour, where they consider it necessary, in their land-use planning and development policies and, in particular, with a view to improving the ecological coherence of the Natura 2000 network, to encourage the management of features of the landscape which are of major importance for wild fauna and flora. Such features are those which, by virtue of their linear and continuous structure (such as rivers with their banks or the traditional systems for marking field boundaries) or their function as stepping-stones (such as ponds or small woods), are essential for the migration, dispersal and genetic exchange of wild species”.

Considering hedgerow length, England has 78% and 67% of the GB and the UK totals respectively (Carey and others 2008; Cooper and others 2009). Detail on the extent and quality of hedgerows specifically in England can be found in Section 3.1.

In a European context, hedgerows occur in at least 26 countries (Müller 2013). Jongman and Bunce (2009) note that hedgerows and tree lines can be found in all European environmental zones. However, estimates of the length or densities of hedgerows are available for very few European countries.

Zanden and others (2013) presented the first map of the density of ‘green lines’ across the EU. Green lines are defined as lines of trees and bushes, including hedges, all less than 3 m in width, together with dry stone walls. The map shows the greatest density of green lines to be across the island of Ireland, south-west England and south-west Wales, the West Midlands of England, north-west France and parts of central and south-western France. Other areas with high densities of hedgerows include the rest of England, northern Netherlands and Germany, and Denmark. However, the inclusion of drystone walls within the term ‘green lines’ leads to uncertainties in these results since they are the predominant type of field boundary in many European countries and in some parts of the UK.

Müller (2013) estimated the length of earth banks (with or without shrubs or trees on top of them) across the 27 European countries he surveyed as 419,000 km, with the Republic of Ireland having by far the greatest length at 140,000 km, followed by Germany with 90,000 km, the UK and France (each about 50,000 km.). The sources of this information, however, vary widely in quality and figures cannot be directly compared with confidence.

These two sources of pan-European information suggest, simply in terms of quantity, that the UK is among the better hedged countries in Europe, perhaps only surpassed in their density by the Republic of Ireland. Dirkmaat (2012) expresses the view that the only European countries where hedgerows still remain on a large scale are Ireland, Britain and France.

In terms of quality, Countryside Survey 2007 provides two measures which enable comparison between the hedgerows of England and those of other GB countries: mean number of native woody species per 30 m length, and structural condition of ‘managed’ hedgerows (that is, those which are neither relict features nor lines of trees). The mean number of woody species in England was 3.7 (per 30 m length), less than in Wales (4.2) but more than in Scotland (2.2) (Carey and others 2008).

With regard to condition, the Countryside Survey data showed that in England 50% of managed hedgerows were in good condition in 2007, including criteria for the height of the base of the hedgerow canopy, cross sectional area, hedgerow ‘gappiness’ and the absence of non-native species. This is a higher proportion than for either Wales or Scotland (44% and 36% respectively). Taking the width of undisturbed ground (greater than 2 m from the hedgerow centreline to reach good condition) and width of perennial vegetation (greater than 1 m) into account as well, the proportion of hedgerows next to arable land in England that were in good condition fell to 12%, a figure which is again higher than for either Wales or Scotland (7% and 11% respectively).

Only anecdotal information, or grey literature, is available to compare hedgerow quality in the UK with that of other European countries. Ecologists and countryside managers visiting the UK frequently remark on the high quality of UK hedgerows for example, Jaap Dirkmaat and Georg Müller (both pers. comm.). UK hedgerows are matched in quality at a regional scale it seems only by the hedges in the bocage landscapes of France (Wolton and others 2010), and perhaps by those in the Republic of Ireland.

In summary, available evidence suggests that hedgerow habitat in England is exceptional, although not unique, in a European context. However, changes in the extent of different types of hedgerows (between managed features and lines of trees) and the small proportion of hedgerows in good condition substantially limits the ability of hedgerows to support thriving wildlife.

1.3 Ecosystem context

Types of habitat in which hedgerows are present

Hedgerows are ubiquitous across lowland England and some parts of the uplands with enclosed fields. Along with dry stone walls, they are a defining feature of farmed landscapes in this country (for example, Rackham 1986). They also occur in urban areas, within or around gardens, parks, etc. Urban hedgerows are often comprised mainly of non-native woody species – when this is so, they do not fall within the scope of this definition.

Hedgerows may be found within nearly all forms of land use, although most frequently in farmland alongside arable or grassland fields. They are, however, also common in cities, towns and villages. Occasionally the edges of woodlands are managed as hedgerows. They frequently form the boundaries to other Priority Habitats, especially species-rich grasslands and orchards, and link others like semi-natural woodlands, lowland heathlands and ponds. Hedgerows are frequently found alongside arable field margins managed for wildlife. Only in the unenclosed uplands, in districts where stone walls are the predominant form of field boundary, and in fenlands and grazing marshes where ditches take their place, are they largely absent.

As a habitat, hedgerows are in effect lines of scrub or woodland, and resemble woodland edges. A summary of the woody and herbaceous species commonly found in hedgerows in England is given in the description of hedgerows (Section 1.1).

Hedgerows' role in supporting biodiversity

Hedgerows are considered vital for the survival of many farmland plants and animals, especially so in intensive agricultural systems (Dover 2019). On an organic farm in Somerset, Evans and others (2011), researching food webs associated with seed-eating animals (of which 82% were invertebrates), noted that the majority of the biodiversity on a farm can be conserved by appropriately managing uncultivated habitats such as hedgerows and woodlands. A further study at the same farm explored the trophic interactions between 560 taxa and found that hedgerows and waste ground, together comprising just 4.5% of the total area of the farm, were disproportionately important to the integrity of the overall ecological network (Evans and others 2013).

Likewise, the occurrence of managed hedgerows was shown to be a key component of environmental heterogeneity and consequently bird species richness in Countryside Survey 2000 (Carrasco and others 2018). Hedgerow plant species provide pollen and nectar resources for a substantial proportion of wild pollinator species. Flowers on woody species which can occur in hedgerows are visited by 95 wild bee, 161 hoverfly and 28 butterfly species in the UK, while flowers of all species recorded in hedgerow quadrats in Countryside Survey 2007 (including ground flora) are visited by 180 bee, 196 hoverfly and 52 butterfly species (Redhead and others 2018; Countryside Survey 2007 hedgerow plant data). Woody hedgerow flowers were included in a recent analysis of the amount of habitat needed to conserve populations of wild pollinators, recognising the importance of hedgerow species in supporting pollinating invertebrates and pollination services (Dicks and others 2015). A particular advantage that hedgerows have for pollinators over other habitats is that they can provide nectar sources throughout the period when adults are flying, from willow catkins and blackthorn flowers in early spring to ivy flowers in autumn (Kremen and others 2019). There is some evidence that hedgerows provide a more valuable forage resource for pollinators in more intensively managed landscapes (less than 5% semi-natural habitat, Garratt and others 2017).

A single hedgerow can support high numbers of species of fungi, plants and animals. Over-mature/senescent trees and deadwood in hedges may provide valuable fungal and lichen habitats (Coppins and others 2001; Bosanquet and others 2018). Wolton (2015) recorded 2,070 species of animals, plants and fungi in a single hedgerow in Devon over a two-year period. These included 17% of the total British list for each of Diptera, Lepidoptera and Trichoptera. Observation and published articles (for example, Cranmer and others 2012; Hinsley & Bellamy 2000; Merckx and others 2010a) strongly suggested that the great majority of the 2,070 species recorded were benefiting from resources provided by the hedges, for food, breeding, finding mates or safe movement through the landscape. While few species are wholly dependent on the hedgerow for all the resources needed to complete their life cycles, nevertheless loss of local hedgerows, or changes in hedgerow management leading to declines in hedgerow quality, would be likely to result in significant population declines for many species (Wolton and others 2014b).

Hedgerows’ role in connecting other habitats

Characteristically, hedgerows form networks which spread across farmed landscapes, significantly broken only by major rivers, roads and railways (although these are often bordered by hedgerows or bands of scrub or woodland which enhance connectivity). They are the most frequent semi-natural habitat linking other Priority Habitats such as semi-natural woodlands and grasslands, heathlands, traditional orchards and ponds and other habitats too, such as patches of scrub and of ruderal vegetation around farm buildings.

Hedgerows are widely considered to play an important role as corridors for day-to-day (commuting) movement (as opposed to dispersal) of mobile taxa, and potentially for increasing landscape permeability (for example, Lawton and others 2010; Frey-Ehrenbold and others 2013). For example, three times as many movements of woodland birds have been recorded along hedgerows as across open fields (Bellamy & Hinsley 2005); similarly butterflies (Dover & Sparks 2000), moths (Coulthard 2012) and bumblebees (Cranmer and others 2007) all preferentially fly along them, while both bats (Cowan & Crompton 2004) and hazel dormice (Bright 1998) find gaps in hedgerow networks can limit day-to-day movements.

In general, however, limited evidence is available for the role of hedgerows in facilitating dispersal of either animals or plants (Kirby 1995; Davies & Pullin 2007). In Sweden, trees with animal dispersed seeds are more frequent in landscapes with connected hedgerow networks than those with poorly connected landscapes (Sarlöv Herlin & Fry 2000). In East Anglia, marsh tit juveniles have difficulty in dispersing between woods where these are further than 200 m apart unless connected by hedgerows (Broughton & Hinsley 2015). Conversely, hedgerows may at times be a barrier to movement for those animals which inhabit open fields, for example some carabid beetle species (for example, García and others 2000).

Trees outside woodlands (TOWs) in hedgerows

Trees outside woodlands are of high biodiversity value, with hedgerows providing the majority of them in lowland rural landscapes. Feber (2017) noted that “Trees outside woods (TOWs), such as copses, hedgerows, scattered trees and orchards, make important contributions to the connectivity and ecological functioning of rural and urban landscapes, in particular through reducing the impacts of habitat fragmentation. Studies from the UK, taken together with evidence from other countries, suggest the contributions of TOWs within the landscape to be overwhelmingly positive.”

Merckx and others (2009) found that the presence of hedgerow trees resulted in a substantially higher abundance (+60%) and species richness (+38%) of larger moths in the immediate landscape compared to similar landscapes without hedgerow trees, although they only studied landscapes subject to an agri-environment scheme (that is, Environmental Stewardship). In a follow-up study, they showed that in typically exposed agricultural landscapes this effect was largely due to the shelter provided by hedgerow trees, rather than to provision of larval food (Merckx and others 2010a). Nevertheless, species that fed as larvae on trees and shrubs benefited more from the presence of hedgerow trees than those that did not. In a further paper they confirmed that hedgerow trees led to a local increase in macro-moth species richness, but not to an increase in abundance, across all farmland (regardless of whether or not it was in an agri-environment scheme; Merckx and others 2012). Slade and others (2013) showed that TOWs act as “stepping-stones” for macro-moths moving across an agricultural landscape, especially when the connectivity of TOWs was increased by being positioned within hedgerows. Merckx and colleagues concluded that it is likely that hedgerow trees are ecologically keystone structures in intensive agricultural landscapes, with a disproportionate effect on ecosystem functioning, given the small area occupied by any individual tree. TOWs provide habitat for saproxylic invertebrates (Alexander and others 2016). TOWs are particularly important for lichens because the trees tend to be open grown with higher light levels reaching the lower branches and boles (Coppins and others 2001).

TOWs may help preserve the genetic integrity of woodlands by maintaining genetic connectivity between woodland patches (Feber 2017). Trees outside woods may facilitate gene flow across fragmented landscapes, helping trees to overcome the problems associated with small populations (Breed and others 2011). Scattered trees are potentially important in helping trees, and the fauna and flora that depend on them, adapt to climate change (Manning and others 2009). With regard to the ever-increasing number of tree diseases and pests coming into England, Feber (2017) noted that it is possible that TOWs may have a greater chance of survival against some such as ash dieback and be important suppliers of seed in the future. On the other hand, TOWs may facilitate disease transmission from one woodland patch to another.

Hedgerows and delivery of broader ecosystem services

Hedgerows deliver many ecosystem services, for the most part dependent on their biodiversity (Wolton 2018; Westaway and Smith 2019). These include regulatory services like water and air purification, soil conservation, flood risk reduction, carbon capture and storage, crop pollination and pest control, and shelter and shade for livestock and crops (Wolton and others 2014a; Garratt and others 2017; Holden and others 2019). Other services include wood fuel provision, livestock fodder, landscape attractiveness, culture and history, and health and wellbeing. In the UK, they are increasingly being promoted as part of agroforestry systems (Raskin & Osborn 2019).

Through their delivery of various ecosystem services, hedgerows can influence the condition of other Priority Habitats. For example, they can benefit the biodiversity associated with rivers and wetlands through improved water quality, that of woodlands through increasing landscape connectivity, and that of arable field margins and of traditional orchards through providing essential complementary food resources for pollinators.

2. Units and attributes

2.1 Natural range and distribution

Hedgerows are largely man-made features which were historically planted with the specific purpose of dividing up rural land and preventing the movement of stock between land parcels. In urban areas, they have mainly been planted to create boundaries between properties, for aesthetic or wildlife reasons within gardens and parks, or for screening purposes. Their range, and how they are distributed within it, is therefore dependent on the presence of land managed by humans. Since they consist primarily of shrubs (many of which are thorny and thicket forming) and trees, their range is associated with that of shrubby and/or woodland habitats.

Rural hedgerows are primarily found across the English lowlands and marginal uplands in enclosed farmland. The range and distribution of the hedgerow Priority Habitat can be measured in density, or length per unit area. Countryside Survey produced estimates for England (based on CEH Land classes, Bunce and others 1996) in '000 km (Countryside Survey 2009). The Environmental Information Data Centre (Brown and others 2016) provides a measure of hedgerow and woody linear feature density (included within the definition of hedgerows) in km per km^2 for each land class. The unit area used for this hedgerow FCS to define natural range and distribution is National Character Areas (NCAs), subdivisions of England based on landscape, biodiversity, geodiversity and economic activity. It is possible to use Countryside Survey data to look at hedgerow density in NCAs but results have to be treated with some caution as the sampling strategy of Countryside Survey is not designed to provide robust information at NCA level.

2.2 Extent

Hedgerows are generally measured as linear habitats and therefore the most appropriate units are lengths (m or km) rather than areas.

Although by definition less than 5 m wide between major woody stems at the base, hedgerows vary in width according to the stage in the management cycle they are in. Newly planted or newly laid hedgerows will be much narrower than the same hedgerows when allowed to develop into lines of trees. The feature retains the same length, but its width ebbs and flows with time according to management, or lack of it.

Where appropriate, it may be useful to consider the density of hedgerows in the landscape as an appropriate metric (for example, length in m per ha or km per km^2). Density is used as a proxy for connectivity in this FCS document, as no alternative data or measures of hedgerow connectivity at a national scale are currently available.

For national reporting the Countryside Survey produced estimates in total length (in '000km) for England, for rural hedges. See Section 3.1 for discussion of alternative sources of data (for example, National Forest Inventory) on hedgerow length in England.

2.3 Structure and function attributes

The value of a hedgerow in supporting biodiversity and associated ecosystem services is determined by several attributes including its structure, size, woody species composition, position in the landscape, adjacent land use, and the impact of non-native species, nutrient enrichment and pesticides. Hedgerow structure may be complex, providing a range of habitats and food provision throughout the year not found elsewhere within the surrounding agricultural matrix (Graham and others 2018).

The structure and function attributes necessary for good quality hedgerows are described below. Table 2 lists the current favourable condition attributes set by Hedgelink (Defra 2007). Table 3 summarises additional structural and functional attributes for which there is good evidence they should be included in defining a good quality hedgerow, and a good quality network of hedgerows. Evidence for the importance of these attributes is summarised briefly below.

There is strong evidence for the role of many structure and function attributes in determining hedgerow quality for biodiversity, across a range of taxa. Some examples of this evidence are included in the text describing each attribute below, but it is not possible to review all evidence in this document. Table 4 (after Graham and others 2018) summarises 64 studies which address how one or more hedgerow quality attribute(s) effect species of herbaceous plants, mammals, bats, birds and/or invertebrates.

Table 2 Favourable condition attributes set by Hedgelink (Defra 2007), relating to the quality of individual hedgerows

	Attribute		Threshold	Notes
1	Size	1.1	Height greater than 1.0 m	Average height excluding bank
		1.2	Width greater than 1.5 m	Average width across canopy
		1.3	Cross-sectional area greater than 3 m²	Width multiplied by height
2	Gaps	2.1	Along length less than 10%	Ignore gateways
		2.2	No gaps greater than 5 m	N/A
		2.3	Gap between ground and base of canopy less than 0.5 m	Not applicable to lines of trees, only to shrubby hedgerows
3	Undisturbed ground	3.1	Greater than 2 m from centreline of hedgerow	Not applicable where hedge bordered by roads, tracks, etc.
4	Herbaceous vegetation	4.1	Greater than 1 m somewhere between centreline and start of cultivated ground	Applies only to perennial vegetation. Not applicable where hedge bordered by roads, tracks, etc. Pasture fields automatically qualify
5		5.1	Woody species less than 10% non-native	Only applies to recently-introduced species –

	Attribute		Threshold	Notes
	Lack of non-native species			archaeophytes count as natives.
		5.2	Herbaceous species less than 10% non-native	As for woody species.
6	Lack of nutrient enrichment	6.1	Less than 20% combined cover of nettles, cleavers and docks	Estimate cover of these species along the side of the hedge being assessed. Note: nutrient enrichment may be due to a number of factors including fertiliser run-off or atmospheric deposition.

Table 3 Additional attributes to describe hedgerow quality, in relation to structure or function

Number	Attribute	Structural or functional	Rationale (further detail and examples are given in the text below this table)
7	Structural complexity within individual hedgerow	Structural	More structural complexity results in a greater range of niches. Greater hedgerow woody density can benefit many invertebrates and birds. Many hedgerow species, including Priority and Farmland Indicator species, need multiple structural components to complete their life cycles.
8	Structural diversity across network	Structural	A full range of hedgerow structures, from newly layed or planted hedges, through short, thick, dense hedgerows and those that are ready to lay or coppice, to lines of trees, maximises the range of niches available for wildlife and so species richness.
9	Connectivity across network	Functional	Connectivity to other hedges, scrub and woodland patches aids daily foraging movement of species and may facilitate dispersal and movement across landscape to help mitigate climate change. There is a potential risk of spreading pests and diseases and, for some species (e.g. linnets) increasing predation (e.g. by corvids).
10	Plant species richness	Functional	High animal species richness is linked to high plant species richness, both of woody species (trees and shrubs) and of herbaceous plants.
11	Standard hedgerow tree numbers, diversity and	Structural and functional	Hedgerow trees provide additional resources, greater structural complexity and can support

Number	Attribute	Structural or functional	Rationale (further detail and examples are given in the text below this table)
	age, at a network level		movement of mobile species along hedgerows.
12	Provision of flowers throughout spring / summer and berries for overwintering wildlife	Functional	A plentiful supply of nectar and pollen, provided by diverse species of woody and herbaceous plants from early spring to late summer, is desirable. So too, is a plentiful supply of berries over-winter from multiple woody species.
13	Lack of pesticide (insecticide or herbicide) application	Functional	Herbicide spray, drift or run off can decrease the quality of hedgerow basal flora, while insecticides can have both lethal and sub-lethal impacts on invertebrates and their predators, thereby reducing biodiversity.
14	Lack of water stress	Functional	Water stress, resulting from drought or lowered water tables through field drainage, can lead to increased plant mortality, especially of trees, and increased susceptibility to pests and pathogens. It can also lead to reduced flowering and fruit production. Cultivation close to hedgerows may also lead to water stress.
15	Invasive pests and diseases, at hedgerow network level	Functional	Invasive plants can out compete or smother low growing herbs, reducing species richness, while invasive pests like grey squirrels can have adverse impacts such as harming tree regeneration. Pathogens like ash dieback disease can have serious deleterious consequences.
16	Presence of dead and decaying wood	Functional	Decaying wood originating from hedgerow shrubs and trees is important for large numbers of species, especially saproxylic fungi and invertebrates. Its quality and abundance are heavily influenced by hedgerow management.

Structure attributes

Key structural attributes include hedgerow size (height, width and length; Table 2). Most species benefit from wider, taller hedgerows, though there are some exceptions (for example, yellowhammers *Emberiza citrinella* may prefer shorter hedges; Hinsley & Bellamy 2019). Generally, wider hedgerows provide more shelter and a more diverse structure for a range of taxa. Hedgerows with large, frequent gaps (Table 2) have been shown to disadvantage a range of taxa (Graeme and others 2018), including bats, other small mammals and some invertebrates (Garratt and others 2017).

The structural complexity, woody biomass and density of hedgerows are key attributes for invertebrates, birds, mammals and plants (Tables 3 & 4). The majority of invertebrates benefit from denser, more complex hedgerow structures (for example, Maudsley, Seeley & Lewis 2002), though some invertebrate predator and parasitoid species may achieve greater population density in less complex vegetation structures (Table 4). Hedgerow structural complexity and density are strongly affected by management. Hedgerow networks with a diverse structure, a range of woody plant ages and variation in time since last management (Table 3) across the network provide a greater range of niches, for example affecting breeding bird success through the provision of nesting sites in dead and decaying woody vegetation (Hinsley & Bellamy 2000).

Hedgerow tree presence is another important structural attribute (Table 3). For example, wood mouse (*Apodemus sylvaticus*) density is increased by the presence of hedgerow trees, potentially due to increased seed availability (Gelling and others 2007). Large moth abundance and diversity were increased by the presence of trees (Merckx and others 2009), while movement of moths between forest patches was facilitated by trees along hedgerows (Slade and others 2013). Hedgerows with large ancient trees with veteran features are an important habitat resource for old-growth invertebrates of dead and decaying wood (Clements & Alexander 2009). Networks of hedgerows with old mature trees can support a range of such species similar to that of substantial areas of ancient semi-natural woodland or wood-pasture, including good numbers of scarce species. TOWs, including hedgerow trees, are known to be important for the daily movements of several bat species, providing foraging habitat and increasing habitat connectivity between foraging and roosting areas (Feber 2017). The presence of trees is one of the most important factors influencing hedgerow bird fauna (Hinsley & Bellamy 2019). As well as being a rich source of seed, fruit and invertebrate food, they also provide song posts for birds like yellowhammers and cavities for hole-nesting birds like kestrel (*Falco tinnunculus)*, stock dove (*Columba oenas*) and owls.

Other structural components as well as the shrubs and trees are critical to hedgerow quality for a range of taxa, that is, the hedge base (including any bank), the vegetated strip adjacent to the hedgerow and any associated ditch (Table 3). An analysis of Priority Species and Farmland Indicator species significantly associated with hedgerows found that the majority (65% of species) are dependent on more than one component, with over a third (35%) being dependent on three or more components. 42% of species were at least partially dependent for resources on the base (under the hedge) and 40% on the vegetated strips associated with hedgerows, with just 9% dependent in part on any ditch (Wolton and others 2013).

Species that are known to use hedgerow bases extensively include bastard balm (*Melittis melissophyllum*), common carder bee (*Bombus pascuorum*), common lizard (*Zootoca vivipara*), dunnock (*Prunella modularis*) and hedgehog (*Erinaceus europaeus*), those using vegetated strips associated with hedgerows include gatekeeper (*Pyronia tithonus*), grey partridge (*Perdix perdix*), turtle dove (*Streptopelia turtur*), song thrush (*Turdus philomelos*), goldfinch (*Carduelis carduelis*), harvest mouse (*Micromys minutus*) and ground nesting birds, and species that use ditches associated with hedgerows include great-crested newt (*Triturus cristatus*), common toad (*Bufo bufo*), grass snake (*Natrix helvetica*) and reed bunting (*Emberiza schoeniclus*). All these will be affected by the quality of the hedgerow bases, marginal strips or ditches, and therefore by the management of these features. Their quality is determined largely by vegetation structure and diversity (Table 2), but other factors such as connectivity and insecticides may have a strong influence.

Function attributes

Hedgerow structure and function is largely determined by hedgerow management, which has immediate and long-term effects on the biodiversity supported by hedgerows (for example, Staley and others 2013). Cutting less frequently than every year, cutting in late winter and not cutting back to the same height and width each time (Table 3) benefits some invertebrates, and the provision of floral and berry resources (Staley and others 2018). The most beneficial time of year for hedgerow cutting may depend on the requirements of specific conservation priority species (for example, Staley and others 2018). Low frequency rejuvenation management such as hedge-laying or coppicing is necessary to encourage woody growth at the base of hedgerows, reduce hedgerow gappiness (Staley and others 2015) and increase the density of foliage (Amy and others 2015). However, management itself is not an attribute of hedgerow quality so is not listed in the table above, rather it is a major factor determining (not describing) quality.

Hedgerow quality is influenced by the presence of non-native species and by the management of field margins, especially by cultivation close to the hedge base (Barr and others 2005). Undisturbed ground within 2 m of the hedgerow centre is part of the current condition assessment, as is the width of perennial vegetation between the hedgerow centre and disturbed ground which should be at least 1 m in width (Table 2).

Plant species richness and diversity of hedgerows is a key attribute (Table 3). Reflecting this, the standard hedgerow survey methodology includes counting the number of woody species in a 30 m hedgerow length (Defra 2007). A diversity of woody species creates a more heterogeneous structure and can provide a greater range of resources, for example a longer flowering season for pollinating invertebrates (Staley and others 2018). Woody species richness has a positive effect on bird species richness (Arnold 1983), and invertebrate numbers (Garratt and others 2017). Dormouse population density in hedgerows is strongly influenced by shrub diversity – intensively managed, low diversity hedgerows lack dormice (Bright & MacPherson 2002). The herbaceous species composition of hedgerow bases and immediate margins is another functional attribute (Table 3).

Hedgerow flowers are used by a wide range of invertebrate species, feeding on pollen, nectar and the petals. The quantity of hedgerow flowers was included in a recent assessment of farmland floral resources needed to support six focal pollinator species (Dicks and others 2015), demonstrating their role in supporting pollinator populations (Table 3). Also, the length of season flowers are available is important, for example, willow catkins and blackthorn flower early, through to late flowering ivy (Staley and others 2018). Pollinators emerging in early spring (for example, queen bumblebees) may be particularly dependent on early hedgerow floral resources, due to the shortage of other flowering resources at this time in the wider agricultural landscape (Dicks and others 2015). Hedgerow berries provide a food resource for overwintering bird, mammal and invertebrate species (Table 3), with hawthorn berries favoured by thrushes species (Sparks & Martin 1999). Many invertebrate species feed on the fleshy fruits of woody hedgerow species, around a quarter of which are classified as rare or scarce (Jefferson 2004).

Hedgerows can be an important source of decaying wood at a landscape scale – such wood is essential for large numbers of saproxylic fungi and invertebrates, including many threatened and scarce species (Alexander and others 2016). The larvae of 137 species of Diptera (17% of the total) which were recorded at a single hedgerow (Wolton and others 2014b) are associated with decaying wood (and associated fungi). The amount of decaying wood present is heavily influenced by management. Retention of veteran trees is critical, but keeping small pieces of dead wood, either attached to the living plant or lying on the ground is also important.

Nutrient enrichment, in particular from fertilizer applied to adjacent crops but also through atmospheric deposition (Table 2), is another major factor which can decrease the quality of the associated vegetated strip (Critchley and others 2010), as is the level of contamination by pesticides such as herbicides and insecticides (Botías and others 2019; Table 3).

Connectivity to other hedgerows and other semi-natural habitats (for example, woodlands, scrub) is another key attribute of hedges for many mobile taxa (Table 2). For example, bumblebees used well-connected hedgerows more, resulting in greater seed set for plants next to connected hedges (Cranmer and others 2012). Continuity of hedgerow canopy is also important for some species of bats and small mammals which avoid hedgerows with gaps (Feber and others 2019). Connectivity may become increasingly important if hedgerows are to form corridors for additional movement under future climate change (Lawtonand others 2010), thereby playing an important role in facilitating landscape connectivity. However, while there is strong evidence that hedgerows support regular movement (for example, for foraging) for a range of mobile taxa, the potential for hedges to facilitate population movement to mitigate against climate change is largely unproven. Finally, there is a potential risk to increasing connectivity of hedges, as it may facilitate the movement of tree pests and diseases (Feber 2017). See Section 1.3 for further information about the importance of hedgerow connectivity, both in terms of everyday movements and dispersal.

Water stress, resulting from drought or lowered water tables through field drainage, can lead to increased plant mortality, especially of trees, and increased susceptibility to pests and pathogens (Defra 2018). It can also lead to reduced flowers and fruit (Table 3).

The hedgerow condition attributes used for biodiversity metrics are identical to those in Table 2, with the addition of an attribute for current damage, “greater than 90% of the hedgerow or undisturbed ground is free of damage caused by human activities", which include pollution, piles of manure or inappropriate cutting practices (Crosher and others 2019b, Table TS1-2). This additional hedgerow biodiversity metric attribute is covered by the extra attributes proposed here in Tables 2 and 3 (Undisturbed ground, Nutrient enrichment, Lack of pesticide application).

The quality of hedgerows and their networks also has the capacity to exert significant effects of the quality for biodiversity of other habitats, including Priority Habitats. Examples include the export of pollinator services, natural enemies and worms as soil improvers. Improvement of water quality in aquatic habitats is another example, through the removal of pollutants by hedgerows. These attributes are not covered further in this assessment because they do not affect the biodiversity of hedgerows *per se*.

Not all attributes that may influence habitat quality are listed in Tables 2 and 3, as some attributes are species specific and therefore not widely applicable. For example, hedgerow shape can alter microclimate, in turn affecting some invertebrates, but the optimal shape is likely to vary with species requirements. The brown hairstreak butterfly (classed as vulnerable on the butterfly red list; Fox and others 2022) lays its eggs on young blackthorn shoots, and prefers to oviposit on hedgerows with a scalloped rather than linear edge, as this creates more shelter and a warmer microclimate (Merckx & Berwaerts 2010).

Table 4 provides a summary of the current evidence for the role of some hedgerow features in determining the habitat quality of a hedgerow for a range of taxonomic groups across 64 papers. Using a vote counting method, + (positive) or * (negative) indicate the direction of the relationship observed, 0 indicates no observed relationship. Where multiple symbols are displayed, an effect was observed in multiple results or studies. Where no evidence for this relationship was encountered in this review, the cell is empty. The number of votes shared across each row or column is given in brackets. Note Table 4 is taken from a recent review of the effects of hedgerow structure on taxa but does not include all the necessary attributes listed in Tables 2 and 3.

Table 4 Summary of the current evidence for the role of some hedgerow features in determining the habitat quality of a hedgerow for a range of taxonomic groups across 64 papers. Reproduced from Graham and others (2018) with permission from Elsevier Ltd. Empty cells indicate there is no evidence for the relationship.

Woody vegetation feature:	herbaceous plants (16)	mammals (18)	bats (14)	birds (24)	invertebrates (19)	lepidoptera (13)
Surface area & volume (8)	++	++	+	+	+	+

Woody vegetation feature:	**herbaceous plants (16)**	**mammals (18)**	**bats (14)**	**birds (24)**	**invertebrates (19)**	**lepidoptera (13)**
Hedgerow height (14)	0**	+++	++	++++*	0	
Hedgerow width (14)	+	++++	+++	++++	++	
Woody biomass/density (21)	++***	+++	++**	+++*	++++	+
Structural complexity & layering (7)		0	*	++	++	+
Species diversity/richness (3)		+		+	+	
Species composition (6)	+			++	+	++
Foliage quality (2)					++	
Foliage quantity (4)					++	++
Berry and flower resources (7)				++	++	+++
Diversity of age structure (5)	+			+	+	++
Connectivity (13)	+++	+++*	+++	++		+

3. Evidence

All blocks of evidence are assigned one of three confidence levels (High, Moderate, Low), based on the quality of the evidence, its applicability and the level of agreement.

The matrix in Figure 1 is used to assess the confidence level assigned to blocks of evidence. White = High confidence; Light blue = Moderate confidence and Dark blue = Low confidence.

Limited evidence Strong agreement	Medium evidence Strong agreement	Robust evidence Strong agreement
Limited evidence Medium agreement	Medium evidence Medium agreement	Robust evidence Medium agreement
Limited evidence Weak agreement	Medium evidence Weak agreement	Robust evidence Weak agreement

Figure 1 Matrix used to assign confidence to blocks of evidence (after IPCC 2010).

Quality of evidence is defined as follows:

- Robust evidence is that which has been reported in peer-reviewed literature, or other reputable literature, from well-designed experiments, surveys or inventories that shows signs of being applicable generally.

- Medium evidence is that reported from well-designed experiments, surveys or inventories but from only one or a small number of sites, with uncertainty over its more general applicability, or is correlational or circumstantial evidence.

- Limited evidence includes 'expert opinion', based on knowledge of ecological factors that plausibly suggest an effect, but there is no circumstantial or direct evidence available.

Agreement is defined as follows:

- Strong agreement is consensus across the literature and amongst those with expertise on the habitat or species.

- Medium agreement is common consensus across the literature and amongst experts but there are some differing papers or reports and/or some differences of opinion.

- Weak agreement is little consensus across the literature and amongst experts and, possibly, many different findings and/or opinions.

3.1 Current situation

Natural range and distribution

The current extent of the hedgerow Priority Habitat reflects historic and present-day agricultural and social practices, with the range and distribution of hedgerows dependent on agricultural and urban land management and the underlying biophysical variables determining it. Modelled estimates of lengths of hedgerows in products produced by the Centre for Ecology and Hydrology (CEH; including the woody linear feature map[1] and mapped estimates based on the Countryside Survey stratification[2]) provide spatial information on the range and distribution of hedgerows (in length per unit area) in rural land across GB and England. Both use Countryside Survey 2007 (a randomly stratified sample-based survey of the UK based on field data collection) which provided an estimate of woody linear features in GB and England in '000's km. The survey in 2007 was the fourth in a series to provide data on hedgerow extent and change (1984, 1990, 1998 and 2007). A more recent National Forest Inventory (NFI) report on Tree Cover outside Woodlands in GB (using sample based aerial photography; Brewer and others 2019) also assessed hedgerow extent at national scales in '000km. The definition of hedgerows used for the NFI differed from the one stated above (Section 1.1) and estimates were quite different, as shown below.

It is possible to use Countryside Survey data to look at hedgerow density in NCAs (Figure 2, Table 5) but results have to be treated with some caution as the sampling strategy of Countryside Survey is not designed to provide robust information at NCA level. However, using Countryside Survey data, land class information on both cover of Arable/Improved grassland Broad Habitats and lengths of hedgerows at NCA levels indicates that all NCAs contain some hedgerows. NCAs with less than 1 km/km^2 included the North Pennines and the Howgill Fells NCAs, both of which contain low proportions of arable and improved grassland. Those with the highest proportions of hedgerows included the Mendip Hills, South Devon and the Hereford Plateau with an average of greater than 50% cover of Arable/Improved grassland.

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[1] https://catalogue.ceh.ac.uk/documents/d7da6cb9-104b-4dbc-b709-c1f7ba94fb16

[2] https://catalogue.ceh.ac.uk/documents/fc65177d-b113-420e-a70b-05d3f42682d5

Table 5 Estimated lengths of hedgerows per 1 km^2 for NCAs across England. Table 5 results are only indicative, as the sampling strategy of Countryside Survey is not designed to provide robust information at NCA level. See Appendix 2 for list of NCA names by number.

Length (km)	Percentage of NCAs	NCA numbers
Less than 2	6	4,5,8,10,17,18,21,34,36
Less than 3.5	15	1,2,3,9,11,12,16,19,25,33,35,46,51,52,53,54,77,80,81,98,123,126,137,159
Less than 4.5	25	6,7,13,14,15,20,22,27,31,37,40,41,42,43,44,45,47,48,56,63,65,78,79,82,94,99,110,113,116,119,124,125,127,130,132,134,135,142,150
Less than 5.5	39	23,24,26,29,30,32,38,39,49,50,55,57,58,59,60,61,62,64,66,67,68,69,70,71,72,73,74,75,76,83,84,85,86,87,88,89,90,91,92,93,95,96,100,102,107,108,109,111,114,115,120,121,122,128,129,131,133,136,138,140,145
Greater than 5.5	15	97,101,103,104,105,106,112,117,118,139,141,143,144,146,147,148,149,151,152,153,154,155,156,157

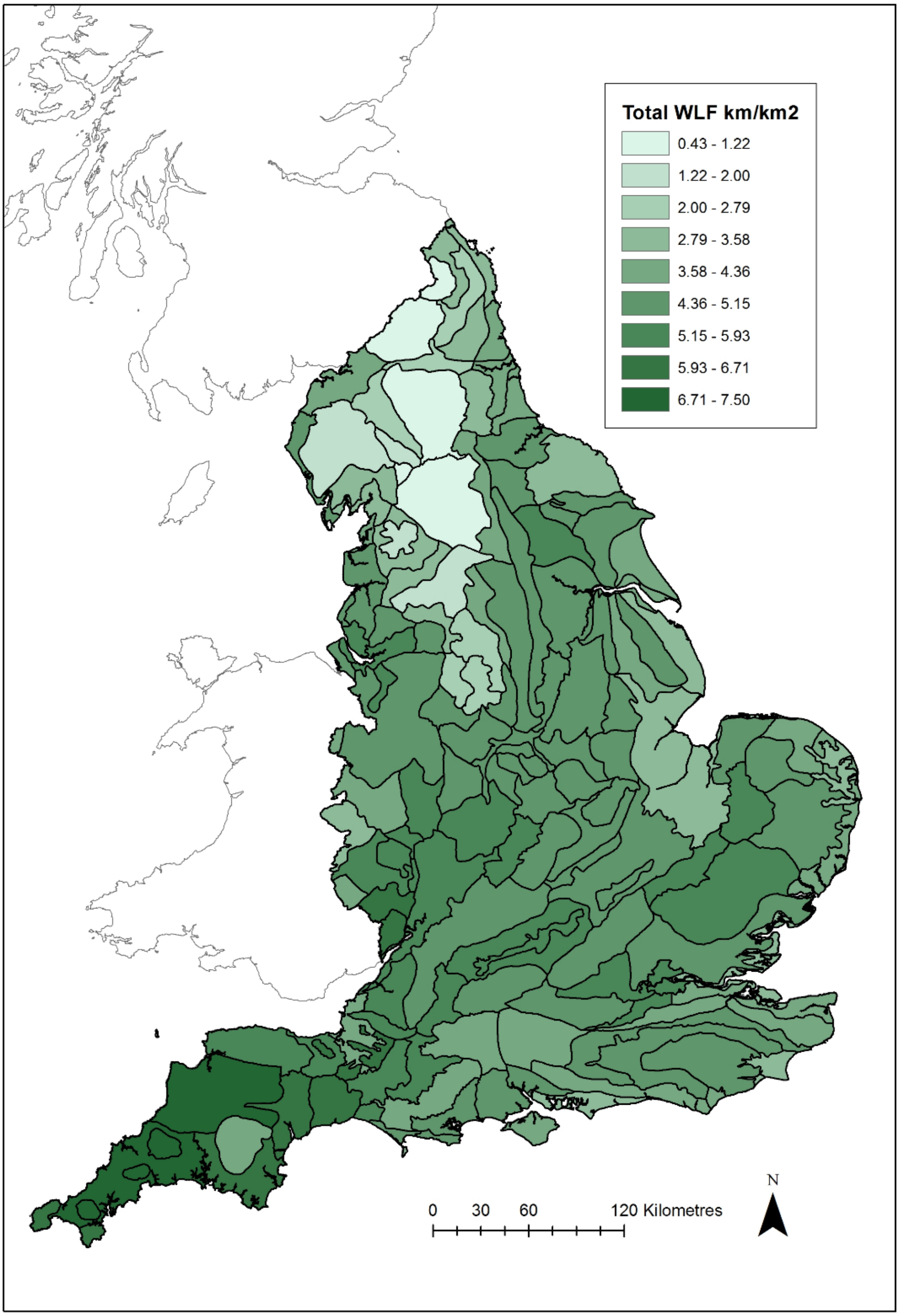

Figure 2 Map of the density of woody linear features in England and Wales in 2007 (data extrapolated from the Countryside Survey randomly stratified sample). The legend provides measures in km per km^2. The boundaries shown are for National Character Areas (NCAs).

Extent

The most accurate recent estimates of rural hedgerow length at country scale come from the Countryside Survey 2007, which estimated the extent of hedgerows in England as 547,000 km ± 20.1 (confidence interval). This is the length of managed hedgerow, lines of trees and relict hedgerow (that is, woody linear feature). These figures equate to an average density of 4.3 km of hedgerow for every 1 km square of England. However, if habitats in which hedgerows don’t tend to occur (or aren’t recorded in Countryside Survey) are excluded the average density estimate is 4.52 km per km^2.

As a field-based study, Countryside Survey uses tight definitions of woody linear feature types in order to enable assessments of change over time. More recent products based on Earth Observation (EO) data are rather more limited in being able to define feature types rigorously and are hence less accurate (although some work is being done to assess the future potential of products which combine field and EO data, Section 4.1). The woody linear feature spatial product for GB hedges, based on the earth observed NEXTMAP data collected in 2007, estimated the extent of hedgerows as 333,000 km (Scholefield and others 2016) and the National Forest Inventory (NFI) reported 336,180 km ± 8% SE (‘000s km) for England (Brewer and others 2019). Discrepancies between estimates are primarily due to methodological differences but also due to differences in definitions of hedgerows. Modelled EO data use coarser definitions as a result of the resolution at which the data they use is collected and are limited to what can be measured from aerial interpretation, although both included the use of some field survey data for validation.

National estimates derived from earth observed (EO) information including aerial photography, underestimate hedgerow length particularly in cases where hedgerows or lines of trees may be in close proximity and parallel to one another, where a managed hedgerow lies on the same boundary as a line of trees but underneath it, or where hedgerows are difficult to distinguish from walls due to close trimming (height and width). The failure to recognise close parallel hedgerows, such as those that border green lanes, is particularly serious since these typically support higher levels of biodiversity than other hedgerows (Dover and others 2000).

The Rural Payment Agency (RPA)/Ordnance Survey database which was developed to enable Greening provisions linked to the Basic Payment Scheme and has not been made available for use in determining extents of hedgerows.

Around 2016, the NFI estimated the length of urban hedgerow in England to be 31,000 km (Brewer and others 2019), approximately one tenth the length of rural hedgerow (305,100 km). This is the only available estimate for urban hedgerow length. A high proportion of urban hedgerows are likely not to be Priority Habitat, having a less than 80% cover of native species. A 2009 survey of 63 hedgerows in Bristol found only 51% to meet the Priority Habitat definition (unpublished report to Defra).

Confidence level (for current length of rural hedgerow in England): High

Connectivity

Connectivity is relevant is this context since it can affect how much species use hedgerows (for example, Cranmer and others 2012; see Sections 1.3 and 2.2 for details). In the absence of national data on hedgerow connectivity, hedgerow density in the landscape may be a proxy measure for connectivity. The current density estimate for rural hedgerows in habitats likely to contain hedgerows (for example, excluding unenclosed moorland and urban areas) is 4.52 km per km^2 (further details above)

Confidence level (for current density of rural hedgerows in relevant habitats in England): High

Quality of habitat patches

In terms of hedgerow quality, Countryside Survey (2007) is the only national dataset which has systematically recorded hedgerow condition across GB. This data provides both a picture of the condition of hedgerows in 2007 and measures which enable comparison between England and the other GB countries. Condition measures of 'managed' hedgerows (that is, not relict features including lines of trees) are shown in Table 6. Countryside Survey also records condition measures in plots on lines of trees (of which there are far fewer than those on managed hedgerows), but the measures recorded are more relevant to managed hedgerows (for example, gappiness, height of base of canopy).

Table 6 Condition measures of managed hedgerows (from Defra Hedgerow Survey Handbook 2007)

Structural condition criteria	Margin condition criteria
Height greater than 1 m	Distance between centre of hedge and disturbed ground greater than 2 m
Width greater than 1.5 m	Width of perennial vegetation 1.0 m
Horizontal gappiness less than 10%	
No gaps greater than 5 m	
Non-native species at greater than 10% cover	
Height of base of canopy less than 0.5 m	

With regard to structural condition, the Countryside Survey (CS) data showed that in England only 50% of managed hedgerows were in good condition in 2007, as assessed by the cross-sectional area, the height of the base of the shrub canopy and gappiness. In Countryside Survey the absence of non-native species was also (wrongly) included as a structural element which contributed to that 50%, but only 2% of hedgerows failed on presence of non-native species. Only 32% of managed hedgerows were in good structural condition and had 2 m or more or undisturbed ground between the centreline of the hedgerow and cultivated land. This figure fell to just 12% where arable land alone was considered.

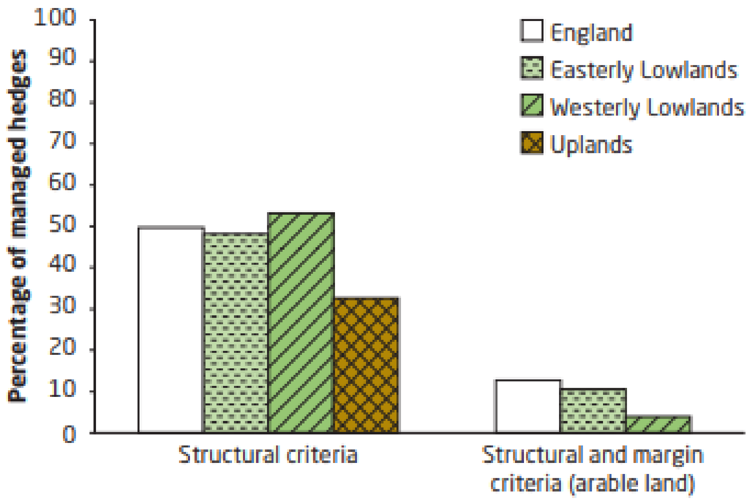

Figure 3 The proportion of 30 m long hedgerow diversity plots in managed hedgerows in England, and the Environmental zones in which condition criteria were met. N.B. No upland hedgerows met all criteria (as shown). National data are not available for many of the quality attributes in Section 1.3, such as flower and berry provision.

Confidence level (for quality of individual rural hedgerows) based on structural attributes: High.

Threatened species

Hedgerows provide important resources for many threatened species in England, such that the loss of hedgerows would be likely to lead to significant population declines. Appendix 1 lists 82 Priority Species (Section 41 species) which are red-listed in Great Britain using IUCN criteria, or which are likely to be red-listed when evaluated. This information was derived from Wolton and others (2013) and relevant published species status reviews. Further red-listed species, or declining species likely to be red-listed once evaluated, are associated with hedgerows but are not Priority Species.

Confidence level (that hedgerows provide significant resources for many threatened species): High.

To exemplify the impact of hedgerow quality and extent on threatened species, a brief account is given below for ten species. These have been selected to cover both a wide range of taxonomic groups and to between them demonstrate the impact of hedgerow quality (across key components - shrub layer, trees, base and margins), as well as the effects of loss of hedgerows and of connectivity.

1. **Copse bindweed** *Fallopia dumetorum*. Vulnerable. A climbing annual of hedges, thickets and wood borders on well-drained soils. Erratic in appearance, it sometimes occurs in quantity following the felling, thinning or coppicing of hedgerows and woodland

([Plant Atlas 2020](#)). The herb is now largely restricted to hedge bottoms and green lanes (Wilson 2019). This species is likely to be sensitive to a lack of hedgerow management, in particular laying or coppicing, and to eutrophication, whether from adjacent land or atmospheric nitrogen deposition. The species range has contracted substantially since about 1950. The extent to which this reflects changes in hedgerow condition is unknown.

Confidence level (that changes in hedgerow condition and extent are a major cause of decline): Moderate.

2. **Orange-fruited elm-lichen** *Caloplaca luteoalba*. Endangered. Native and formerly widespread, it is now occasional in lowland Britain, mostly in eastern England and Scotland. Populations declined rapidly after the outbreak of Dutch elm disease in the 1970s, as many of the host trees were lost. It is threatened by the loss of hedgerow and other wayside trees, and by intensive agriculture leading to excessive nutrient enrichment. Before the advent of Dutch elm disease, elm was its favoured host tree but more recently it has been found occasionally on sycamore, field maple and ash (British Lichen Society). The loss of ash due to ash dieback is likely to be a further cause of decline.

Confidence level (that changes in hedgerow tree condition and extent are a major cause of decline): High.

3. **Brown hairstreak** *Thecla betulae*. Vulnerable. A scarce butterfly of hedgerows, scrub and woodland edge. In the UK, there was a 49% decline in the number of 1 km squares occupied by the Brown hairstreak between 1976 and 2014. Although there are some positive signs of locally increased occupancy over the last decade, the abundance of brown hairstreak continues to decrease (Fox and others 2015). The eggs are laid on the new growth of blackthorn. Adults congregate in the canopy of tall trees, especially ash. The substantial decline in range and population size is attributed to hedgerow removal and annual flailing (Merckx & Berwaerts 2010; Staley and others 2018).

Confidence level (that changes in hedgerow management and hedgerow loss are a major cause of decline): High.

4. **Pale Shining Brown** *Polia bombycina*. Endangered. Now a rare species of farmland, this moth experienced a very severe distribution decline, mainly since the 1970s, and is now restricted to small areas of Wiltshire, Oxfordshire, Hertfordshire and Norfolk (Randle and others 2019). It has an unknown lifecycle, the larvae probably feeding on one or more broadleaved trees or shrubs in the wild. The presence of hedgerow trees has been shown to confer a considerable positive effect on numbers of adults (Merckx and others 2010b). This effect is thought likely to be due to the increased shelter provided by hedgerow trees in comparison to hedgerows without trees, although an increase in night-time temperature beneath hedgerow tree canopies may also play a part.

Confidence level (that changes in hedgerow tree condition and extent are a major cause of decline): Moderate.

5. **Lackey** *Malacosoma neustria*. Vulnerable. This is one of many polyphagous moths associated with farmland and hedgerows which are declining rapidly for unknown reasons. Its abundance and range have decreased severely since the 1970s (Randle and others 2019). Still widespread, it is a moth of open, sunny habitats, especially hedgerows, scrubby places, gardens and open woodland. The larvae are polyphagous on broadleaved trees and shrubs, and their webs are a common sight in hedges.

Confidence level (that changes in hedgerow condition and extent are a major cause of decline): Low.

6. **Turtle dove** *Streptopelia turtur*. Critically Endangered. A summer migrant, this is the most rapidly declining farmland bird, experiencing a 91% decline over the last three generations (16 years; Stanbury and others 2017). Most nest in hedgerows or scrub over four metres tall, and the birds feed in hedgerow margins as well as further in field. It is likely that the availability of nesting habitat dictates turtle dove density, with density being positively related to changes in the amount of hedgerow, scrub and woodland edge per unit area on the farmland (Browne and others 2004). However, lack of seed-rich foraging habitat in close proximity to patches of established scrub (or tall thick hedges) may be the major factor limiting the breeding success of turtle doves (Dunn & Morris 2012).

Confidence level (that changes in hedgerow condition and extent are a major cause of decline): Moderate.

7. **Marsh tit** *Poecile palustris*. Vulnerable. This bird breeds in woodlands but uses hedgerows for feeding and in particular for dispersal. Gaps between woods greater than 100-200 m represent a barrier to movement, and improving woodland connectivity by conserving and planting hedgerows is likely to have clear benefits. Indeed, landscape connectivity is likely to be more important in explaining the decline of this species than woodland management or any other factor (Broughton & Hinsley 2015).

Confidence level (that changes in hedgerow connections between woodlands are a major cause of decline): Moderate.

8. **Barbastelle** *Barbastella barbastellus*. Vulnerable. This bat prefers to forage in riparian and broad-leaved woodlands, but preferentially travels along hedgerows and treelines when moving between foraging and roosting habitats. This is particularly so soon after they leave their roost sites – when it is fully dark they move freely across large open spaces. They also forage along tall hedgerows and tree lines (Zeale and others 2012). The extent to which maternity colonies can use isolated trees as roost sites is unknown. Trends in abundance or distribution are also unknown (Mathews and others 2018).

Confidence level (that changes in hedgerow condition, or in hedgerow connectivity between woodlands, are a major cause of decline): Low.

9. **Hedgehog** *Erinaceus europaeus*. Vulnerable. On farmland, hedgehogs forage, nest and hibernate preferentially along hedgerows and field margins, preferring wide hedgerows with dense bases in which to nest (Haigh and others 2012; Hof & Bright 2010).

Their close relationship with hedgerows may also reflect reduced vulnerability to predation from badgers and foxes – populations of hedgehogs and these predators are negatively correlated. The range of hedgehogs appears to have been stable over recent years, but evidence points to a substantial decline in numbers. The species is thought to be sensitive to landscape fragmentation: increased agricultural intensification, including loss of hedgerows and decline in their condition, is thought to be in part at least responsible for their decline (Mathews and others 2018). Moorhouse and others (2014) modelled hedgehog movement across a range of landscapes, and found that doubling the length of hedgerow would result in substantially more movement of hedgehogs in agricultural landscapes (for example, 51% more individual hedgehogs moving 2 km).

Confidence level (that changes in hedgerow extent, condition and connectivity are a major cause of decline): Moderate.

10. **Hazel dormouse** *Muscardinus avellanarius*. Vulnerable. A species of mid-successional woody habitats, hedgerows can support population densities of dormice equal to those of the best woodlands (Bright & MacPherson 2002). They favour wide species-rich hedgerows in well-connected landscapes, being reluctant to cross open ground even when dispersing. The species range is thought to have shrunk from 49 English counties in 1885 to 32 counties today (excluding six counties where reintroductions are currently active). An analysis of data derived from the UK's National Dormouse Monitoring Programme strongly suggests that dormice have suffered a 72% population crash between 1993 and 2014, equivalent to a mean annual rate of decline of 5.8% (Goodwin and others 2017). The population fall is ongoing and thought to be due to the effects of habitat loss and reduction of habitat quality. Changing climatic conditions affecting hibernation, and increasing deer numbers removing undergrowth, may also be factors (Goodwin and others 2018). The species is very vulnerable to unfavourable habitat management, for example the repeated hard annual trimming of hedgerows leads to loss of suitable nesting sites and of food. To achieve Favourable Conservation Status, it will be necessary for hazel dormice to occupy all 49 English counties which were covered by their range in 1885, an expansion from its current range of 32 counties (Morris 2021).

Confidence level (that changes in hedgerow extent, condition and connectivity are a major cause of decline): High.

Hedgerows can have an adverse effect on a few threatened species, such as skylark (*Alauda arvensis*) and lapwing (*Vanellus vanellus*). These species prefer open landscapes without structures offering nesting places or vantage points for corvids and raptors, or movement corridors for predators such as mustelids. Other species like corn bunting (*Emberiza calandra*) prefer short gappy hedgerows (Hinsley & Bellamy 2019).

Support to broader biodiversity

Hedgerows are considered vital for the survival of many farmland plants and animals, especially so in intensive agricultural systems, as detailed in Section 1.3 above. They provide essential complementary resources for many species that utilise a range of different farmland habitats – cropland, woodland, scrub, etc. Hedgerows also influence the biodiversity of adjacent habitats and landscape features through the provision of a number of ecosystem services (see Section 2.3 for details). These services include the export of pollinators and of natural enemies (beneficials), and the removal of pollutants from water improving the quality of aquatic habitats for life.

Confidence level (that changes in hedgerow extent and quality affect broader biodiversity): High.

3.2 Historical variation in the above parameters

Changes in hedgerow length

About two thirds of rural England has had a continuously hedged landscape for six hundred years or more. Some hedgerow systems date back to prehistoric times, and most were well established by 1400 ad. In the Midlands and part of the North East the majority of hedgerows were planted under the Enclosure Acts between 1750 and 1850 (derived from Rackham 1994).

The length of rural hedgerow in England probably reached a peak about 1870, although parts of ancient countryside were as fully hedged in the 15th century (Rackham 1986). Aerial photographs show that hedgerow length remained more or less stable until 1945, but thereafter declined rapidly. It was estimated that there were 662,500 km of hedgerow in England in 1946/7 (Huntingdon Survey and Consultants Ltd. 1986). This figure comes from looking at early photographs which gave an average of 13 miles of hedgerow per square mile (8.1 km per km^2). However, they noted that hedgerow loss was far from even across the country, in particular being greater in arable areas, probably reflecting efficiencies relating to crop production area and machinery size, as well as consolidation of land ownership and management.

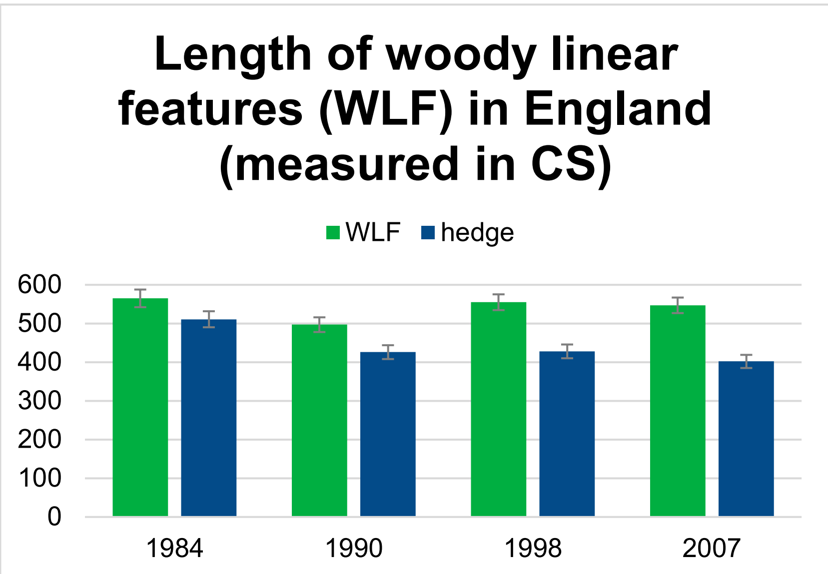

Figure 4 Length (000s km) of hedgerow and woody linear features in England from 1984 to 2007, data from Countryside Survey. The term woody linear feature in this context includes

both planted avenues of trees which are not included in the hedgerow definition (Section 1.1), and relict hedges/lines of trees or scrub which are included

Countryside Survey provides the most accurate figures for the length of rural hedgerow in modern times, distinguishing between woody linear features as a whole and managed hedgerows as a subset of these (Figure 4). Countryside Survey revealed significant losses of hedgerows between 1984 and 1990, most likely due to consolidation of land to form larger, more efficient, agricultural management units (Potter & Lobley 1996). Loss of hedgerows between 1998 and 2007 occurred despite the introduction of the Hedgerows Regulations (1997) in England which halted removal of hedgerows without derogation. All changes were statistically significant. No comparable nationwide estimate of hedgerow length is available post 2007.

Taking the length of woody linear feature to be roughly equivalent to the length of hedgerow, the post WWII decline in rural hedgerow length may have been just 17.4% - down from 662,500 km in England in 1946/7 to 547,000 km in 2007. However, as Wright (2016) observes, not only are losses uneven across the country, but it is also difficult to make comparison between estimates of hedgerow length at different times, because of differences in methodology and the definition of what a hedgerow is. Most authors believe the loss of hedgerows to be closer to 30%, even 50% (Wright 2016). In Devon, for example, the total length of hedgerows in the mid-nineteenth century is thought to have been between 80,000 and 96,000 km, while now it is thought to be 53,000 km, a loss of 33-45% (Devon County Council and the Devon Hedge Group 2014).

No information appears to be available on changes in the length of urban hedgerows.

Confidence (that the length of rural hedgerows has declined significantly): High, with figures for extent of loss being good between 1984 and 2007, but poor subsequently and between 1946/7 and 1984.

Changes in hedgerow tree numbers

Rackham (1986) considers the period 1500 -1750 to have been the heyday of hedgerow trees. This reflected the high value placed on these trees as a source of timber and for firewood. Subsequently standard trees – that is individual trees within a hedgerow allowed to take their natural open-grown shape – probably rose in number with the Enclosure Acts (1750 to 1850). After WWII, numbers almost certainly fell back sharply both through the removal of many hedgerows as described above, and through the use of mechanised hedge trimmers such as flail cutters reducing young tree survival. The arrival of Dutch elm disease in the 1970s was responsible for the loss of many more trees, and we have yet to understand the impact of ash dieback disease on ash trees, which are the most common hedgerow tree. Field drainage and water stress, together with ploughing close to field boundaries and tree roots, both symptomatic of post-war increases in agricultural production, are likely to have killed further trees. More recently, trees have been felled, or not replaced, alongside roads due to safety concerns.

Nevertheless, it is conceivable that England has more full-canopy trees in hedgerows now than ever before, albeit not standard trees present within a managed hedge, but rather hedgerows which have gone unmanaged and deteriorated into lines of trees. Between 1984 and 2007 the length of relict hedgerows and lines of trees in England increased by 248% largely at the expense of managed hedgerows (Countryside Survey 2009).

Between 1998 and 2007, Countryside Survey 2007 revealed a 4.5% (62,000 trees) loss of individual trees (that is, not part of a line or group of trees), with an estimated 1,554,700 trees present in 2007 (Barr and Norton 2009). This loss is statistically significant. In contrast, in 1951 the Forestry Commission estimated England contained 56 million hedgerow and park trees more than 12 inches in girth, and in 1980 62 million non-woodland trees more than 7 cm in diameter (Forestry Commission 1951, in Rackham 1986). The huge difference in these estimates is largely because the Countryside Survey data are for individual trees while the Forestry Commission estimates are for all trees occurring outside of woodlands, including those in lines of trees and small copses. The National Forest Inventory, for a January 2016 mid-point, estimates the number of lone trees including standard hedgerow and other boundary trees to be 11,922,000 in rural situations, and 10,255,000 in urban situations (Brewer and others 2019). Urban areas have typically far higher densities of lone trees than rural ones, although in urban areas comparatively few of these trees are in hedgerows.

Countryside Survey also revealed an apparent dramatic decrease between 1998 and 2007 of 71% in GB numbers of the smallest size class of standard hedgerow trees, less than 3 cm diameter at breast height (DBH). There was, however, a slight increase of 8% in numbers in the next size class, 3-20 cm DBH. It is possible that the decrease in numbers of the smallest size class was exaggerated by a proportion of these trees being disguised within the increasing numbers of hedgerows that are developing into lines of trees. In addition, survey pressures and time constraints might have reduced the likelihood of surveyors recording small trees. However, the 10% decline found for standard trees greater than 20 cm DBH, where the sample size was much larger and the trees much easier to find, is believed to be accurate (Forest Research 2009).

Based on tree mortality and size data available through Countryside Survey, Forest Research (2009) was able to model the population dynamics of standard hedgerow trees. The models revealed that for a stable population of hedgerow trees, 45% of the population needs to have a DBH of 20 cm or less. In 2007, only 19% of trees were in this size range, less than half of the population required. Population declines of hedgerow trees are inevitable if the rate of recruitment remains below that required to replace losses of mature trees. This research was carried out before ash dieback was detected in England, in 2012.

Confidence level that number of hedgerow trees has declined: High for the Countryside Survey results as given (these refer to hedgerow standard trees), but Low more generally because of lack of knowledge about how and where hedgerows are turning into lines of trees.

Changes in hedgerow quality

Changes in hedgerow quality over the last century have not been explicitly measured. Countryside Survey hedgerow condition measures were first produced in CS2007 in response to requests from the Hedgerow Steering Group (now Hedgelink) for more information on condition and there has been no repeat survey of hedgerows in Countryside Survey since. However, some measures from previous Countryside Surveys can be used to provide information on some changes in factors likely to have affected hedgerow quality.

The biggest change in quality may result from the increase in the number of hedgerows that are no longer actively managed and have been permitted either to become lines of trees or mature shrubs, or relict features. For example, the length of managed hedgerows decreased by 6.1% (26,000 km) in England between 1998 and 2007 with a large proportion of these managed hedgerows turning into lines of trees and relict hedgerows (which increased by 13.2% across both categories; Countryside Survey 2009). As already noted, between 1984 and 2007 the length of relict hedgerows and lines of trees increased by 248% indicating a decrease in active hedgerow management. This change is likely to reflect the perceived lack of value of hedgerows to farm businesses, especially with the advent of barbed wire and stock fencing, and availability of cheap coal and other fossil fuels making the management of hedgerows for firewood unnecessary. In particular since WWII there is believed to have been a big reduction in the number of hedgerows layed or coppiced each year, with an increase in widespread hedgerow trimming with a tractor mounted flail. The increase in deer populations is likely to have an adverse impact in many parts of the country on any hedgerow laying or coppicing that has been carried out.

Hedge bottom plant species richness decreased between 1978 and 1998 but stabilised between 1998 and 2007. Plant species characteristic of shaded and/or fertile and less acidic conditions increased between 1978 and 2007 (Countryside Survey 2009). More detail on this is given below.

Confidence level that hedgerow quality has, overall, declined: High (evidence available indicates high confidence in both the loss of well managed hedgerows and associated standard hedgerow trees, but there has been no follow up to the detailed condition measures from the Countryside Survey 2007 survey).

Impact of changes on natural range and distribution

The loss of hedgerows since WWII has not had a marked effect on the range or distribution of hedgerows in England (as opposed to density) since they remain present throughout all those regions and counties where they were historically present. However, arable areas are likely to have seen greater consolidation of land into larger parcels for management than more pastoral landscapes, leading to lower hedgerow densities. It would be possible to investigate this further using historic Countryside Survey data.

Hedgerow trees are unevenly and sparsely distributed across England, and whilst no analysis has been carried out to assess whether there have been changes in range and distribution of hedgerow trees, it is likely that they remain present throughout their former range, albeit at different densities.

Confidence that hedgerow range and distribution (as distinct from density) has not changed: High.

Impact of changes on extent

The degree of loss of hedgerows in terms of their combined length is covered above, as are changes in the numbers of hedgerow trees.

Confidence (that hedgerow area has decreased leading to adverse effects on biodiversity): High.

Impact of changes on patch size and connectivity

Where fragments of hedgerow become isolated or hedgerows cease to be connected to other hedgerows or to other areas of semi-natural habitat, their wildlife value may normally be expected to decrease as patch sizes becomes too small to support species requiring larger areas of continuous habitat. Likewise, loss of hedgerows to lines of trees and relict hedgerows is likely to affect both connectivity between woody linear features at landscape scales (although no analysis has yet been carried out to quantify this), and connectivity more generally. Any decrease in connectivity is likely to have a negative impact on biodiversity, since many species appear to favour hedgerow junctions (Lack 1988) or use hedgerows as corridors between habitat patches (see Section 1.3). This is another potential area for further analysis of spatial Countryside Survey data.

Confidence (that hedgerow connectivity has decreased leading to adverse effects on biodiversity): Moderate.

Impact of changes on quality of habitat patches

As hedgerows are the most significant uncropped habitat on farmland, any changes in quality are likely to have significant impacts not only on the biodiversity, including both common and uncommon species, of hedgerows themselves but also on that across farmland (and on the delivery of associated ecosystem services).

Countryside Survey (2009) reported that along hedgerow bases, there was an increase in plant species characteristic of shaded, fertile or less acidic conditions between 1978 and 2007. This reflects both the increase in the number of hedgerows that had developed into lines of trees and an increase in nutrient status. Grasses became less dominant, competitive species increased and ruderal species decreased, species casting or preferring shade increased, and species preferring fertile conditions increased. Similarly, a comparison of the flora associated with 357 sample hedgerows in southern England in 2001 with data collected between 1931 and1939 found that during this 70-year period hedgerow communities shifted towards species associated with higher soil fertility, a more competitive ecological strategy and, in unmanaged hedgerows, greater shade tolerance (Staley and others 2013).

Both the loss of hedgerow trees (described above) and reduction in the species richness of the hedgerow tree population are likely to affect hedgerow quality and resilience. Any short-term benefit from an increase in veteran or dying standing trees which may benefit wildlife will be lost in the longer term.

Most changes in habitat quality have been driven by changes in management and intensification of adjacent land use, as described below.

Effects of changes in management practices on habitat quality

As outlined above, the main changes in management over the last century have been:

- The introduction of flail cutters. These have facilitated the trimming of hedgerows, including their basal and marginal vegetation, and are now used widely, often on an annual basis.
- The reduction in hedgerow laying and coppicing, actions necessary to rejuvenate woody growth at the bottom of hedgerows through restarting the process of succession (exacerbated by the increase in deer populations).
- The cessation of management altogether allowing hedgerows to develop into lines of trees or mature bushes or to become relict features.
- The wire fencing of hedgerows leading to changes in hedge base, bank and margin flora, through preventing grazing and trampling (which can be either beneficial or harmful to species-richness, depending on levels), and limiting options for machine management.

Changes in hedgerow trimming

Cutting hedgerows back hard to the same point annually substantially reduces the abundance of flowers and fruits produced by hedgerows (Staley and others 2012a) with consequent adverse effects on wildlife, such as moths, bees, wintering birds and small mammals (for example, Staley and others 2016). It also reduces the abundance and species-richness of some invertebrate groups, although others may increase (Barr and others 2005; Staley and others 2016). Although bushy hedgerows produced by regular trimming provide good nesting habitat for many small birds, hard annual trimming increases the susceptibility of nests to predation and lowers breeding success (Lack 1987). Mechanised cutting of hedge bottoms and immediate margins is also likely to impact on wildlife: whilst some low-growing herbaceous plants may benefit, arthropods and small mammals may suffer, especially if bramble and suckering blackthorn, etc. growths are removed.

Mechanised trimming has also been partly responsible for the decline in numbers of standard hedgerow trees (Barr and others 2005). Standards above managed features provide structural heterogeneity in boundary features – it is likely that the variety of habitats provided by having both standards and a managed hedgerow exceeds that of a line of trees alone. Although generally considered highly beneficial for wildlife, the presence of hedgerow trees can have an adverse effect on some birds, both infield and in the hedgerow, through providing nesting sites for corvids (Hinsley & Bellamy 2019). Countryside Survey (2009) showed that the majority of hedgerows in England were managed by cutting both in 1998 (53%) and in 2007 (56%).

Changes in hedge laying and coppicing

Periodic laying or coppicing of hedgerows is a way of rejuvenating hedgerows, resulting in new growth that improves their vigour and long-term stability and reduces gappiness. Increasing the density of hedgerows through rejuvenation management such as hedgerow laying has been shown to increase the number of invertebrates in hedges, with increased density of foliage leading to more herbivores and predators (Amy and others 2015).

Reduction in hedgerow laying and coppicing leads to hedgerows either becoming moribund if they continue to be trimmed on a regular basis over a long period, or to them developing into lines of trees of mature bushes (Staley and others 2015). As they become moribund, they become increasingly gappy along the length of the hedgerow and beneath its canopy, a process which is unfavourable to much wildlife. There were significant decreases in the lengths of hedgerows in England that were newly planted or were managed by laying or coppicing between 1998 and 2007 (Countryside Survey 2009).

There may be some negative impacts of laying and coppicing when traditional techniques are followed, as is frequently required under agri-environment schemes. Traditional hedge laying often, for example, involves the removal of elder (*Sambucus nigra*) as it creates gaps. Elder is, however, a tree of considerable wildlife value so its removal may be detrimental to some wildlife. Likewise, dead and decaying wood are often removed when hedgerows are layed or coppiced, and brambles, roses and other ramblers and climbers stripped out, actions again likely to impoverish the biodiversity within hedgerows. The decline in hedge laying and coppicing may therefore have been of benefit to some species, for example saprophytic fungi. New hedgerow rejuvenation techniques such as conservation hedge laying or wildlife hedging can support abundances of invertebrates comparable or even higher than traditional hedge laying (Amy and others 2015) but are as yet rarely used.

Cessation of management

Loss of managed hedgerows to lines of trees is likely to impact on the many species which require compact, dense structures in which to nest and live, including woodland plant species associated with a closed canopy (Barr and others 2005). Deterioration of managed features into individual trees with gaps between them radically changes the type of habitat available and the species which occupy that habitat. Lines of trees can cast dense shade on banks, verges and other marginal herbaceous vegetation, resulting in changes in plant communities and often an increase in bare earth. The cessation of management, especially in pastoral land use systems and where hedgerows are not protected by fencing, ultimately results in rapid gap formation (Staley and others 2015).

Effects of fencing

Fencing hedgerows both protects hedge bottom and marginal vegetation from potentially damaging levels of grazing, and results in changes in plant communities due to removal of livestock and deer grazing and hindering management with machinery. Typically, low-growing and annual herbs are lost, to be replaced by tall herbs, coarse grasses and bramble (Critchley and others 2010). Patches of bare soil which can be important to nesting solitary bees and wasps, especially on the south-facing side of banks, may also be lost. The vegetation also tends to become far more uniform, losing the diversity of structures that is important to many animals, for example bees. Hedgerows that are layed or coppiced in pastoral areas, or arable areas where deer pressures are high, are now nearly always fenced.

Effects of use of artificial fertilizers

The application of NPK fertilizers to grass and croplands has resulted in an increase in the frequency of nettle *Urtica dioica* and goosegrass *Galium aparine* along hedge bases, to the extent that these are often dominant, reducing plant species richness and excluding some other herbs (Stuart and others 2005; Smart and others 2006).

Heavy fertilizer use typical of arable systems has also led to an increase in elder *Sambucus nigra* which in turn has altered the structure of hedges, causing gaps. Increases in bramble (from the 14th most commonly recorded species in Countryside Survey in 1990 to 7th in 2007) (Carey and others 2008a) may result from nutrient enrichment, with, like elder, both benefits and disbenefits to wildlife.

Effects of use of pesticides

As may be expected, the use of herbicides and insecticides on adjacent crops has been found to have an adverse impact on hedgerow wildlife, either through direct application, through spray drift, or carried in solution in water (Botías and others 2019). Impacts can be sub-lethal as well as lethal.

Confidence level (that changes in hedgerow quality have, overall, had an adverse impact on biodiversity): High.

Effects of changes in quality of hedgerow trees

Declines in numbers of standard trees will have had an adverse impact on the presence and abundance of a large range of taxa associated with full canopy trees including lichen, fungi, epiphytes, invertebrates, mammals and roosting birds and bats and moths (see Section 1.3 for more information on the value of hedgerow trees for wildlife). The presence of standard hedgerow trees in managed hedgerows are known to facilitate the movement of some animals through farmed landscapes, for example moths, as described in Section 3.1. Lines of trees may also facilitate animal movement but gappy features or lines of shrubs may be less suitable.

The loss of elm trees will have had a negative impact on those species wholly or partially dependent on them, for example the White-letter hairstreak butterfly *Satyrium w-album*

(Forest Research 2009). The likely impact of the current ongoing loss of ash trees due to ash dieback is covered in 3.3 below.

Confidence level (that changes in the number and diversity of standard hedgerow trees quality have had an adverse impact on biodiversity): Moderate.

Effect of changes on threatened species

This section examines the impact of the above changes in habitat extent and quality on threatened species through the ten exemplar species chosen in 3.1 (see 3.1 for references).

The decline in the length of hedgerow in England since WWII is likely to have had an adverse impact on all ten species through reducing population sizes since all ten are reliant on hedgerows to provide some of the resources they require for survival or reproduction.

Marsh tit, barbastelle bat and hazel dormouse are known to use hedgerows not only as sources of food but also as movement corridors, the tit for juvenile dispersal, the bat and dormouse for movement through the landscape during everyday activities. The loss of hedgerows and subsequent decline in landscape connectivity will therefore have adversely affected these species.

Changes in hedgerow management are likely to have impacted on several of the species. Copse bindweed, a plant that responds to the high light levels resulting from coppicing and laying, is likely to have declined partly as a result of the current low levels of these traditional practices. Brown hairstreak butterflies lay their eggs on the new growth of blackthorn and are believed to have been severely affected by the widespread practice of hard annual trimming with flail cutters. Turtle doves favour tall thick hedgerows for nesting so may have benefitted from many hedgerows being allowed to grow into lines of trees, especially lines of hawthorns and blackthorns if they remain dense and bushy. Hedgehogs prefer wide hedges with dense bases for nesting, so management which has led to gaps between the ground and canopy base will have had an adverse effect. Such management includes repeated hard trimming over many years, high livestock pressure on unfenced hedgerows, herbicide application or drift, and abandonment.

The abundance of orange-fruited elm-lichen was severely reduced through the loss of mature elm trees growing in hedgerows and similar non-woodland situations and may be further impacted by the loss of ash trees. This species prefers the high light conditions prevalent on the trunks of standard trees, so the decline in numbers of these as opposed to trees growing in lines of trees is another factor. The pale shining brown moth is another species dependent on hedgerow trees, probably for shelter.

Eutrophication is likely to have been harmful for copse bindweed.

The reasons for decline in the lackey moth are, as with several other threatened moth species and many other invertebrates, currently unknown, but it is probable that some aspect of hedgerow quality is one of the drivers. The lethal or sub-lethal effects of insecticides are likely to be a factor. Hypothetically, a change in foliage palatability as a result of artificial nutrient enrichment may be another. In urban situations and other places with high levels of artificial light at night, light pollution may be having a significant adverse effect on many insects (Grubisic and others 2018).

Confidence level that changes in hedgerow and hedgerow tree quality has, in general, had an adverse impact on threatened species: High.

3.3 The future for the habitat and its conservation

Current pressures and threats

Apart from direct hedgerow removal, which still occurs but not at the scale experienced in the mid to late 20th century, all the pressures and threats described in the previous Section (3.2) continue to this day largely unabated. Looking ahead, new or increased threats come in particular from climate change and the arrival of further pests and diseases. A focus on managing hedgerows either to store more carbon or as a source of green energy in the form of wood fuel is likely to result in changes to the habitat.

Rural hedgerow removal is currently controlled by the 1997 Hedgerows Regulations, which effectively prohibit the removal of a high proportion of rural hedgerows over 30 years old without local authority consent. Most urban hedgerows are, however, not protected, and removal of hedgerows in general is often permitted as part of development planning approval. Biodiversity offsetting measures and no net loss requirements should, in theory at least, often compensate for these. Also, some illegal removal of hedgerows can occur. Partial removal of hedgerow components (for example, margins, ditches or trees) is another threat, which may be less likely to be noticed as it is less obvious than full hedgerow removal. Nevertheless, the length of hedgerow being planted or restored under agri-environment schemes in England has increased from1,418 km in 2009 (Natural England 2009) under Environmental Stewardship (ES) to 3,683 km in 2020 under ES and Countryside Stewardship.

Interest in agro-forestry is rising and this may bring benefits for hedgerow biodiversity through the creation of new hedgerows and improving landscape connectivity.

Among the most severe reasons for the loss of hedgerow condition over the past few decades that continue today are (a) neglect (lack of active management), (b) poor trimming practices and (c) tree pests and diseases. Other significant on-going threats include pesticide use, artificially raised nutrient levels (eutrophication), intensive grazing, and tree pests and diseases.

Hard annual trimming with a flail, which results in deterioration in hedgerow structure and quality (and sometimes total loss), remains commonplace, although there are no more up to date figures on its frequency than Countryside Survey 2007. There has been a decrease over the last 10 years in the length of hedgerow managed using more sympathetic trimming regimes under agri-environment schemes, from 185,448 km under

Environmental Stewardship in 2009 (Natural England 2009), to 72,179 km under a combination of Countryside Stewardship and Environmental Stewardship in 2020[3].

The population of standard hedgerow trees remains under threat and is almost certainly continuing to decline since the last set of figures (Countryside Survey 2007), reflecting a continued lack of recruitment and increased stress from further agricultural intensification and climate change. The situation is exacerbated by ash dieback (affecting our most common hedgerow tree), and by other pests and diseases such as grey squirrels and acute oak disease (oak is our second most common hedgerow tree). This disease is anticipated to kill 90% or more of ashes – since this is the most frequent tree species in England (Maskell and others 2013), a far greater rate of recruitment of standard hedgerow tree species (other than ash) is now required to prevent further severe decline in overall numbers.

Pesticide applications (both herbicides and insecticides) also continue to pose a threat to hedgerow habitats, especially to the flora and fauna in the base of hedges.

Eutrophication, in particular nitrogen deposition from the air or run-off from adjacent fields, is another threat to hedgerow basal flora, and is likely to lead to a homogenisation of hedgerow basal plant communities, dominated by a few competitive, fast-growing species. Increased nitrogen deposition is also having a detrimental impact on the relationship between trees and their associated mycorrhizal fungi (van der Linde and others 2018).

Intensive grazing is a further factor causing loss of herbaceous plant species in the base of hedges, as well as the erosion of hedge banks. Heavy grazing by sheep in particular can reduce foliage of woody hedgerow plants towards the base of hedgerows, leaving them more gappy (Wilson 2019). Poaching by animals and compaction of soil by animal and farm machinery may also be having an impact on tree and hedgerow quality.

Climate change is a current and ongoing influence on hedgerow habitats, though little direct evidence is currently available to inform the details or directions of likely impacts on biodiversity. Shrubs and especially trees, often already stressed by unsympathetic management such as close ploughing or by disease, are vulnerable to extreme weather events such as summer droughts. Climate change may exacerbate the risk of new pests and diseases becoming established. If, on a landscape scale, hedgerows are to be encouraged to become wider and taller to increase the amount of carbon stored, or if they are managed primarily on a coppice rotation without top trimming to enable them to produce large wood fuel crops, biodiversity losses may follow.

[3] https://naturalengland-defra.opendata.arcgis.com/datasets/environmental-stewardship-scheme-options-england; https://naturalengland-defra.opendata.arcgis.com/datasets/countryside-stewardship-scheme-2016-management-options-england

Please see Section 3.2 for more detail on the above threats and pressures.

Natural range and distribution

Although the range and distribution of hedgerows across England are not placed under immediate threat from the above threats and pressures, nevertheless if they are not checked in the long-term hedgerow networks will become increasing broken and ecologically dysfunctional. An increased emphasis on the retention, rejuvenation and restoration of hedgerows throughout their range is required, together with compensatory planting for those that have been removed or otherwise been lost.

The strong evidence that hedgerow extent should be increased substantially (below and Section 4.2) raises the question of whether this increase should be broadly similar across the natural range of hedges, or if biodiversity benefits would be maximised by focusing increases in particular landscape types or NCAs. There may also be an opportunity to create new approaches to hedgerows (in terms of their extent, composition and management) in landscapes where hedgerows do not currently feature heavily, and/ or where historically, hedgerow extent has reduced to a greater extent. However, evidence on the landscape contexts in which an increase in hedgerow extent (and density) would most benefit biodiversity is lacking.

There is limited evidence that the impact of hedgerows on some taxa may be moderated by local landscape characteristics, for example in relation to their support of pollinating invertebrates. Garratt and others (2017) showed that hedgerows are a more valuable forage resource for pollinators in more intensively managed landscapes (less than 5% cover of semi-natural habitat), compared with landscapes with a high coverage of semi-natural habitat. Other studies have suggested that conservation efforts (including the increase or restoration of target habitats) may be most effective in intermediate landscapes, where the ongoing presence of species pools may support colonisation of newly established habitats (Rappaport and others 2015; Spake and others 2019). In the context of agri-environment management in general, there is evidence that efficacy for pollinating invertebrates is greatest in landscapes of intermediate complexity (greater than 2% cover of semi-natural habitat; Concepción and others 2012) and in arable rather than grassland systems (Scheper and others 2013). However, with the exception of Garratt and others (2017), none of these studies relate specifically to hedgerow restoration, but instead review general efficacy of a range of agri-environment management, or theoretical restoration of other target habitats.

There is an urgent need for evidence to address this knowledge gap specifically for hedgerows, given the substantial increase in hedgerow extent recommended both here and the 40% increase in hedgerow length recently recommended in the context of climate change mitigation (Committee on Climate Change 2019). This needs to be addressed both in terms of optimal placement of new hedgerows to provide habitat to support biodiversity (a role of hedgerows for which there is strong evidence, Section 1.3), and optimal placement to increase connectivity (for which less evidence is available, Section 1.3).

Confidence (that retention of existing range and distribution is necessary to maintain associated biodiversity): High.

Extent and connectivity

Current hedgerow length in England is 547,000 km (details in Section 3.1) and average hedgerow densities in England (within their range) are equivalent to 4.52 km per km^2. In some areas of the country, densities are higher than this in accordance with smaller field sizes and types of cropping, while in others, densities are much lower (Section 3.1). There is some evidence for optimal length and density of hedgerows to support biodiversity, including one study which relates to a threatened species (European hedgehogs, Section 3.1). The available evidence (detailed below) supports a substantial increase in both the length and density of hedgerows, and an increase in the number of hedgerow trees for FCS. Optimal levels of hedgerow connectivity are likely to be highly species dependent. For example, the requirements of herbs, wingless invertebrates, butterflies and birds are very different. In creation of new hedgerows or restoration of existing habitats, increasing both density and connectivity should be priorities.

Moorhouse and others (2014) modelled the movement of European hedgehogs in lowland farmland in England with double or triple the current extent of hedgerows. They found that doubling the total length of hedgerows would substantially enhance population connectivity for hedgehogs, but that trebling the length would provide little additional connectivity, as hedgehog movement did not increase between the two scenarios of doubling or tripling hedgerows (Moorhouse and others 2014). Morris (2020) recommends hedgerow restoration through planting new hedges for conservation of dormice, though does not specify an optimal length of hedge. In an analysis of the amount of flowering habitat required on farmland to support wild pollinators, Dicks and others (2015) suggested 13.8 km of flowering hedgerow (per km^2) could provide pollen and nectar for six common farmland bee species, in combination with flowers from other habitats (for example, pollen and nectar mixes planted under agri-environment schemes). Fuller and others (2001) show bird species richness increases with hedgerow length up to around 8 km / km^2, and then starts to drop again for hedgerow lengths greater than 12 km. Carrasco and others (2018) suggest the maximum bird species richness is reached at a shorter length (approximately 1,600 m), but their analysis showed species richness doesn’t drop as hedgerow length increases beyond this and takes no account of bird abundance. Besnard and others (2014) recommend no more than approximately 9.5 km / km^2 hedgerow as the maximum for habitat patches to support at least one species of grassland bird. Overall, these few studies for hedgehogs, some bird and bee species indicate that biodiversity would be benefitted by an increase in the extent and density of hedgerows in England to around 8-13.8 km / km^2 relative to current amounts. Given the potential for some negative consequences for biodiversity of increases at the top end of this range (9.5-12 km / km^2), the available evidence suggests average hedgerow extent should be increased to around 10 km / km^2.

As discussed above, there is the potential for increased transmission of pests and diseases if hedgerow density and connectivity are increased. There is little evidence quantifying this risk, and indeed Mathews and others (2006) found a decreased risk of bovine tuberculosis (bTB) with increased hedgerow extent and quality (reduced gaps). The main increased risks may, however, relate to tree pests and diseases (Section 1.3).

The number of standard hedgerow trees (as opposed to lines of trees with touching canopies) also needs to be considered in defining future favourable extent, due to the importance of hedgerow trees in supporting a range of taxa (Sections 1.3 and 3.1). Feber (2017) identifies an evidence gap in understanding how to "most effectively optimise the contribution made by TOWs to ecological connectivity and functioning". Nonetheless, a final spacing of one hedgerow tree every 20-40 m has been proposed as optimal for English hedgerows (FWAG SouthWest 2017). One every 40 m equates to 22 million hedgerow trees. This is a 14-fold increase in the number of rural hedgerow trees (current estimate 1.6 million, see Section 3.2). The recommendation is that trees are planted at 20 m to achieve a final density of one every 20-40 m, due to mortality and thinning, so more would need to be planted to achieve this increase.

There is some evidence that other priority habitats may be benefitted by placing them next to existing hedgerows. For example, a more interesting flora may develop if new lowland mixed woodlands are planted next to hedges (Kirby 2017).

Confidence (that increasing hedgerow length and density (as a proxy for connectivity) is necessary to achieve FCS for biodiversity): High.

Quality of habitat patches

Given the importance of favourable hedgerow structure to both their longevity and to their capacity to support biodiversity (Sections 1.3 and 2.3), the current poor condition of over half of England's rural hedgerows is of major concern and a major barrier to the habitat achieving FCS. Section 4.3 details thresholds for the structural and functional quality attributes listed in Section 2.3. The quality of existing and any additional hedgerows in England must be substantially improved, as without this the biodiversity benefits of the increases in extent and density discussed above will not be realised.

Confidence (that restoring and improving hedgerow quality is necessary to achieve Favourable Conservation Status): High.

Increases in hedgerow length and density, and an improvement in hedgerow quality (as detailed above and in Section 2) are required to:

- Ensure that sufficient habitat exists to maintain or restore viable populations of dependent species, both broad farmland biodiversity and rare, scarce or threatened species.
- Restore or enhance connectivity where necessary.
- Boost the export of ecosystem services such as pollination, pest control and water quality improvement to other habitats, including Priority Habitats like orchards and species-rich grasslands.

- Increase habitat resilience in the face of any further agricultural or developmental pressure, new pests and diseases, and climate change, through improved hedgerow quality.

Threatened species

Most of the current pressures and threats are a continuation of past threats, and as a consequence their impact on threatened species is covered in Section 3.2 above. Clearly if there continues to be a net loss of hedgerows this will both reduce habitat extent and connectivity, to the detriment of most, if not all, threatened species. Likewise, the current trend for more powerful pesticides to be used, and for applications to be increasingly frequent, even if overall the amount of pesticides used is falling (Hayhow and others 2019), can only be detrimental. On the other hand, continued reductions in atmospheric nitrogen deposition will benefit hedgerow plants like copse bindweed and bastard balm (*Mellitis melissophyllum*) as well as lichens such as the orange-fruited elm lichen.

Changes due to climate change will accelerate with often unpredictable consequences for species. The likely increased focus on the management of hedgerows both for carbon sequestration and as a source of renewable energy in the form of wood fuel will have an impact, and more hedgerows are likely to cease to receive any management as a result of (re)wilding programmes. Taken together, such changes are likely to have a mixed impact on threatened species. For example, brown hairstreak butterflies, turtle doves and hazel dormice may benefit if hedgerows are permitted to grow wider (for example, through allowing suckering blackthorn to grow unchecked), in the pursuit of increasing carbon capture or (re)wilding. On the other hand, managing hedgerows on a coppice cycle for wood fuel, with little or no trimming, will render them less favourable for dormice since they will no longer have a dense structure during any part of the management cycle – but they may serve barbastelle bats better as movement corridors. Allowing more standard hedgerow trees to grow to maturity as carbon stores will benefit those many threatened species associated with open grown trees outside woodlands, including the pale shining brown moth and lichens. Likewise, more standard trees will increase connectivity and help to compensate for any unfavourable management of the shrub line between the trees.

A reduction in the intensity of agricultural land use, perhaps as a result of new agri-environment schemes or changes in consumer demand (for example, less meat consumption), is likely to benefit many threatened species associated with hedgerows. In particular, a reduction in herbicide and insecticide use will be favourable, as will any reduction in intensive livestock grazing. However, if the hedgerows become subsumed within large blocks of scrub or woodland, for example during (re)wilding, those species which favour edge habitats or which are in part dependent on in-field features may decline.

Confidence (that the current and likely future threats listed will adversely affect hedgerow threatened species, and biodiversity more broadly, unless action taken to reduce their impact): High.

3.4 Constraints to expansion or restoration

Restoration of hedgerows to FCS requires an increase in extent and density, and a substantial increase in the proportion of hedgerows that are in good condition (both discussed in Section 4 below). In theory, with a few exceptions, there are no immovable constraints to achieving these two objectives since the knowledge and technical expertise exists both to plant more hedgerows and to alter the management of the hedgerows themselves and of adjacent land to improve condition. Exceptions are climate change and atmospheric nitrogen deposition, both matters which require action at a global as well as local level, and the impact of pests and diseases which cannot be entirely controlled, but which good biosecurity measures might reduce.

An increase in the extent and density of hedgerows, and improvement in their quality, will have a positive impact on the majority of species supported by hedges. Action to restore hedgerows to FCS needs to be flexible enough to allow heterogeneity in hedgerow management and structure and permit regional or local objectives for hedgerow restoration.

Hedgerows in poor structural condition are likely to need rejuvenation of the woody species to encourage basal growth (for example, by coppicing, laying or a comparable approach such as conservation hedging; Staley and others 2015), and potentially ‘gapping up’ (planting new woody species in large gaps). More generally, hedgerow quality is likely to be better maintained and improved by cutting hedgerows less frequently (than annually), less intensively (to allow a slight increase in height and width), and in most cases in winter rather than autumn (Staley and others 2012b, Staley and others 2016).

Achievement of FCS requires the improvement of other aspects of hedgerow quality beyond structural ones. Many hedgerows have suffered lasting damage as a result of eutrophication, as evidenced by nettles or goosegrass dominating the basal and marginal flora, sometimes to the virtual exclusion of other herbs. Rectifying this can probably be done in most instances but is always challenging and likely to take many years – some improvement may by possible within five years but often ten or more years will be required. Addressing this issue is made more difficult by a lack of knowledge or practical experience of appropriate restoration techniques (Critchley and others 2010).

A reduction in the levels of pesticides reaching hedgerows, whether through spray or dust drift, or through the leaching of soil drenches or seed dressings, will also be required. Again, this can be achieved, but will require radical changes in farming practice, especially on arable land, and the adoption of appropriate organic systems (Botías and others 2019).

Losses due to the impacts of pests and diseases may in some instances be irrecoverable: for example, the loss of mature elms due to Dutch elm disease and the anticipated loss of the majority of ashes due to ash dieback disease. In such cases other tree species with similar ecological traits will need to be planted or otherwise encouraged (Mitchell and others 2014).

It is unlikely that it will be possible to mitigate fully many of the impacts of climate change. Examples include mismatches in phenology leading to breakages in food webs, or winters no longer being cold enough for hibernating animals such as hazel dormice. Some species will increase in abundance and range, and others decrease – this is inevitable and will impact on FCS.

Among Priority Habitats, hedgerows are atypical in that they are not only important as a habitat in their own right but they also substantially impact on the habitats in which they occur or to which they connect. Hence, improvement to the structure, quality, density and connectivity of hedgerows will also benefit the biodiversity of other habitats, especially those of intensively managed farmland but also woodlands, herb-rich grasslands, heathlands, orchards, ponds and patches of scrub vegetation. Just a few species, those that favour wide open expanses, such as lapwings, skylarks and corn buntings, may be at risk from an increase in hedgerow density (Hinsley & Bellamy 2019), but careful planning at a landscape scale should effectively mitigate this risk. An improvement in hedgerow condition will also benefit the wildlife of urban areas (Atkins 2019).

Confidence (that an increase in extent and quality of hedgerows is technically feasible for most parameters, and that it will be beneficial to other habitats and to the majority of species): High.

4. Conclusions

4.1 Favourable range and distribution

At a national scale, the favourable future range for hedgerows remains broadly the same as the current distribution, shown on the map in Section 3.1 (Figure 2). The current range covers the majority of agricultural land within England, with some NCAs with very low densities, for example, the Cheviots, Howgill Fells and Yorkshire Dales, likely due to the use of walls or a lack of enclosure (see Table 5). The density of hedgerow differs across England, with the greatest densities (greater than 7 km per km^2) in Devon and Cornwall, and less than half that density in areas such as Norfolk and the Peak District reflecting biophysical variables and previous agricultural practices.

Increases in the total length, density and quality of hedgerow are all required for FCS as detailed in Section 3.3 and below. This may result in an expansion of the range of hedgerows within regions where some areas or farms currently have few or no hedges. There may be an opportunity to create new approaches to hedgerows (in terms of their extent, composition and management) in landscapes where hedgerows do not currently feature heavily, and/ or where historically, hedgerow extent has reduced to a greater extent. However, evidence on the landscape contexts in which an increase in hedgerow extent (and density) would most benefit biodiversity is lacking, as detailed in Section 3.3 above. There is an urgent need for evidence to address this gap.

In Section 4.2 below, national targets are specified for the length and density of hedgerow required to achieve FCS. The appropriate density and distribution of hedgerows at smaller spatial scales will differ depending on local conservation priorities for threatened species and other habitats, in addition to regional biophysical variables and landscape context as discussed above.

Monitoring the future range, distribution and extent of hedgerows will require similar approaches to previous and current monitoring, summarised in Section 3.1. Countryside Survey has provided the most comprehensive recent data on the extent and condition of hedgerows, but resources to repeat the hedgerow survey component of Countryside Survey (last surveyed in 2007) are not currently available.

Other products have been produced, but none of these promises similar levels of accuracy and repeatability.

1) A woody linear feature map, based on the Land Cover Map (LCM2007) spatial framework and on digital terrain data collected from aerial imagery, informed by CS field data, was produced in 2016 (Scholefield and others 2016). As it was based on aerial imagery, this product did not differentiate between woody linear feature types (that is, those that are lines of trees, managed hedgerows or relict hedges).

2) The Rural Payments Agency (RPA) boundary layer has been produced by the Ordnance Survey for RPA to aid in the administration of agri-environment schemes. This

product is available under licence, and since it uses more detailed parcel level information than the spatial framework for LCM2007 than 1), is potentially a more accurate reflection of the current extent of hedgerows. However, it is unclear on what data the current map was based, whether the Ordnance Survey / RPA hedgerow map will be updated in a rigorous repeatable fashion, and how accessible and accurate the data is. Additionally, unless the data is being collected and updated in a systematic and rigorous fashion it is unlikely to be useful for accurately monitoring future changes in the distribution and extent of hedges.

3) The recent National Forest Inventory (NFI) report on Tree Cover outside Woodlands in GB using sample based aerial photography and some limited ground-truthing (Brewer and others 2019) provided estimates of hedgerow extent at national scales in '000km. The sample used for England was 217 1 km squares (from aerial photography) with 30 field surveys for validation, based on random sampling in NFI regions and data from the National Tree Map (NTMTM) produced by Bluesky International Limited. Estimates produced by NFI are quite different to those produced in Countryside Survey, a more rigorous (289 field surveyed squares) and representative survey (based on an underlying stratification). In addition, they NFI estimates are based on an aerial photography dataset (Bluesky) which is produced for commercial rather than research purposes and which, like the OS/RPA data is not updated in a rigorous or repeatable way to enable consistent measures of change over time.

Current work between CEH and Defra is investigating the potential use of LIDAR data for provision of national level metrics on the distribution, extent and structural condition of hedges. Initial work has focused on matching LIDAR data with Countryside Survey 2007 field data to be able to relate field and EO measures, hence providing the possibility to extend Countryside Survey measures without field survey. However, data limitations, including a paucity of LIDAR data to relate to the 2007 Countryside Survey both spatially and temporally were evident early on. Potentially slow rates of change in hedgerow structure and extent make it possible to relate field data (from 2007) to LIDAR data from other years, but temporal aspects of data collection – both year and time of year may be an important consideration in the potential use of such data to measure changes in the extent (or structural condition) of this Priority Habitat into the future. Where data is present, it has been possible to compare canopy information to boundary datasets – including the Countryside Survey field survey and the RPA boundary product. Ongoing work is investigating the uncertainties around overall extents of woody linear features and seeking to identify whether it is possible to differentiate between feature types (hedgerows versus lines of trees or relict hedges) using the LIDAR data.

Remote sensing data has clear potential to contribute to future monitoring of the extents of woody linear features across England, where consistent methods and repeated national coverage data are available. However, currently none of the remote sensing hedgerow products provide detailed data on the extent and condition of hedgerows that are in any way equivalent to the detailed field data collected within Countryside Survey 2007. Field survey is likely to be a necessary component of monitoring hedgerow distribution, extent and quality in future, in combination with remote sensing datasets, not least to capture data on aspects such as species presence (woody and hedge base flora), height of base of canopy, and management type.

4.2 Favourable extent

As discussed in Section 3.3, the extent for rural hedgerows in England when in FCS is estimated at 882,000 km, equivalent to a density of 10km / km^2 in habitats suitable for hedgerows (for example, Broad Habitats: Arable and Horticultural; Improved Grassland; Neutral Grassland; Calcareous Grassland; Acid Grassland; Boundary and Linear features). This is a 61% increase on the current rural hedgerow length in England of 547,000 km (current density approximately 4.52 km / km^2 in relevant habitats). If urban hedgerows are included, the extent for rural and urban hedgerows in England is 926,000 km. Careful consideration should be given as to where (for example, by NCA) increases in hedgerow density may be most appropriate. Countryside Survey data could be used to explore where loss of hedgerows to lines of trees is occurring, or where landscapes might benefit from the increased habitat and connectivity provided by hedges.

These figures for hedgerow future extent and density were informed by the available evidence for the optimal length or density of hedgerow for wildlife, which is extremely scarce. Only one of the 10 threatened species used as exemplars and detailed in Section 3.1 had associated evidence for optimal hedgerow density. In the absence of specific evidence for most conservation priority species, evidence for the ideal extent of hedgerows more broadly for general biodiversity was considered in setting this increase in hedgerow extent and density, as detailed in Section 3.3.

There is also little evidence for the optimal number of hedgerow trees to support biodiversity, though strong evidence exists on the benefits to biodiversity of the presence of hedgerow trees (Section 1.3). A final spacing of one hedgerow tree every 20-40 m has been proposed as optimal for English hedgerows (FWAG SouthWest 2017). One every 40 m equates to 22 million hedgerow trees. This is a 14-fold increase in the number of rural hedgerow trees (current estimate 1.6 million, see Section 3.2). The recommendation is that trees are planted at 20 m to achieve a final density of one every 20-40 m, due to mortality and thinning, so more will need to be planted to achieve FCS. As above, it may be possible to explore Countryside Survey data on hedgerows further to understand where most benefits would be gained from increase in the numbers of standard trees in hedgerows (taking into account also the likely impacts of ash dieback).

While increasing the extent and density of hedgerow will contribute to this habitat’s capacity to support thriving biodiversity, especially as hedges mature, increasing the quality of the current stock of hedgerows is more important. Furthermore, new hedgerows should be of high quality - increasing the extent of hedges in poor condition is unlikely to provide significant benefit to biodiversity or the ecosystem services supported by hedgerows.

4.3 Favourable structure and function attributes

The main structural and functional attributes determining both individual hedgerow and hedgerow network quality as detailed in Section 2.3. This section presents recommended thresholds for each of these attributes where possible and supporting evidence. At times this evidence is weak, in which case this is stated. Structural and functional attributes are dealt with together reflecting the close interplay between them in the context of hedgerows.

For individual hedgerows, Hedgelink has set thresholds for some favourable condition attributes, namely the ones given in Table 2 in Section 2.3. This table is repeated below for ease of reference (Table 7). While the thresholds given have been informed by scientific studies, the figures given are based largely on expert opinion and have not been subject to rigorous testing to determine whether they are optimal across a wide range of taxonomic groups.

Table 7 Favourable condition attributes set by Hedgelink (Defra 2007), relating to the quality of individual hedgerows

	Attribute		Threshold	Notes
1	Size	1.1	Height greater than 1.0 m	Average height excluding bank
		1.2	Width greater than 1.5 m	Average width across canopy
		1.3	Cross-sectional area greater than 3 m²	Width multiplied by height
2	Gaps	2.1	Along length less than 10%	Ignore gateways
		2.2	No gaps greater than 5 m	N/A
		2.3	Gap between ground and base of canopy less than 0.5 m	Not applicable to lines of trees, only to shrubby hedgerows
3	Undisturbed ground	3.1	Greater than 2 m from centreline of hedgerow	Not applicable where hedge bordered by roads, tracks, etc.
4	Herbaceous vegetation	4.1	Greater than 1 m somewhere between centreline and start of cultivated ground	Applies only to perennial vegetation. Not applicable where hedge bordered by roads, tracks, etc. Pasture fields automatically qualify
5	Lack of non-native species	5.1	Woody species less than 10% non-native	Only applies to recently-introduced species – archaeophytes count as natives.
		5.2	Herbaceous species less than 10% non-native	As for woody species.
6	Lack of nutrient enrichment	6.1	Less than 20% combined cover of nettles, cleavers and docks	Estimate cover of these species along the side of the hedge being assessed.

Attribute			Threshold	Notes
				Note: nutrient enrichment may be due to a number of factors including fertiliser run-off or atmospheric deposition.

These attributes were measured within Countryside Survey 2007 (Countryside Survey 2009) and thus can be monitored at a national level. The standard Hedgelink/Defra hedgerow survey methodology also enables individual hedgerows to be assessed for these attributes (Defra 2007). This methodology is now available through the Peoples' Trust for Endangered Species). Additionally, some species attributes may be available through the National Plant Monitoring Scheme data (where hedgerows are sampled).

Further quality attributes should be considered when determining whether a hedgerow is in FCS or not – a hedgerow could pass all the thresholds for the attributes listed in Table 7 yet still be in unfavourable condition for biodiversity. These further attributes were given in Table 3 in Section 2.3 and are listed in Table 8 below, together with suggested thresholds.

Table 8 Favourable condition attributes, with thresholds. Note that numbers 8, 9, 11 and 15 relate to hedgerow networks, the remainder to individual hedgerows.

Number	Attribute	Threshold	Rationale
7	Structural complexity within individual hedgerow	At least three out of the following five structural components present: • shrub layer • standard trees • basal flora • marginal flora • ditch	More structural complexity results in a greater range of niches. Greater hedgerow woody density can benefit many invertebrates and birds. Many hedgerow species, including Priority and Farmland Indicator species, need multiple structural components to complete their life cycles.
8	Structural diversity across network	50% of hedgerows thick and bushy under a trimming regime, 20% growing up without trimming prior to laying or coppicing, 5% just layed or coppiced, 5% in early stages of re-growth, 5% as lines of trees, and 15% managed for safe access or for screening.	These figures are preliminary only, based on limited expert opinion. While there is good evidence that different species (for example, bird species) favour hedgerows in different states of growth, no evidence is available to enable relative proportions of these stages to be set with any confidence. The figures given are taken from the draft Dormouse Conservation Handbook (3rd edition) (Bullion and others in prep.).
9	Connectivity across network	9.1 - Less than x% of hedgerows not connected at one or both ends to other hedgerows or semi-natural habitats. 9.2 - At least y number of nodes per km^2.	No evidence available as yet to set figures for x or y, pending future analysis of Countryside Survey or EO data and additional research on connectivity for dispersal across a range of taxa. Meanwhile, hedgerow density (see Section 4.1) serves as a proxy measure for connectivity.

Number	Attribute	Threshold	Rationale
10	Plant species richness	10.1 - A minimum of 3.7 woody species per 30 m sample stretch, on average. 10.2 - Herbaceous species richness restored to 1978 levels.	Shrub and tree diversity are important for resilience as well as being linked to high species richness (see 2.3 for details). No evidence has been found to suggest minimum or optimal levels of woody species for any taxonomic groupings. Consequently, the fall-back position is to use the average woody species richness recorded in Countryside Survey 2007 – unchanged from 1998. A threshold for individual hedgerows would be preferable and make more ecological sense. It is probable that hedgerows with just one woody species forming the majority of the canopy should be rated unfavourable.
11	Standard hedgerow tree numbers, diversity and age, at a network level	11.1 - An average of one mature tree present every 20 m to 50 m. 11.2 - At least x different species of tree present per km of hedgerow. 11.3 - 45% of trees need to be 20 cm or less DBH.	11.1 – Please see Sections 3.3 and 4.2 rationale. 11.2 – Further research is required to determine a suitable value for x. Understanding of current / recent species richness could be informed by further analysis of the Countryside Survey 2007 dataset, but evidence is lacking on optimal species richness to support thriving biodiversity. 11.3 - This is the percentage of young trees required for a stable population (Forest Research).
12	Provision of flowers throughout spring / summer and berries for overwintering wildlife	Significant amounts of flowers, berries, nuts, etc., present in at least two years out of every three.	Provision of flowers (for nectar and pollen resources), and berries and nuts, are heavily influenced by the frequency of trimming and by the severity of trimming (Staley and others 2012a).
13	Lack of pesticide (insecticide or herbicide) application	Level at which lethal or sub-lethal effects on non-target organisms are observed.	Where thresholds for toxic effects are unknown, a precautionary approach should be taken, the assumption being that any detectable levels are harmful.
14	Lack of water stress	No hedgerow trees dying through water stress that is preventable through local action.	Water stress, resulting from close ploughing, drought or lowered water tables through field drainage, can lead to increased plant mortality, especially of trees, and increased susceptibility to pests and pathogens. It can also lead to reduced flowering and fruit production and resultant impacts on biodiversity

Number	Attribute	Threshold	Rationale
15	Invasive pests and diseases, at hedgerow network level	Level at which a significant impact is observed on relevant biotic communities, at a landscape scale.	The impact of pests and diseases may be effectively mitigated by remedial actions – for example encouraging other trees with similar ecological traits to grow in place of ash trees killed by ash dieback disease.
16	Presence of dead and decaying wood	At least one standard tree developing veteran features c. every 50 m. All veteran trees, stools, and rotting stumps retained unless they pose a significant risk to safety. Substantial amounts of dead and decaying wood of all sizes retained *in situ* when hedges are layed or coppiced	No evidence is available for the necessary frequency of veteran trees within hedgerow networks to support key saproxylic species: the figure of at least one per 50 m is indicative. Dead and decaying wood is often cleaned away from hedgerows when they are layed or coppiced, either for the sake of neatness or in the mistaken belief that it prevents the spread of pathogens.

A number of other attributes could be considered and developed, to refine the condition assessment of hedgerows. These include atmospheric nitrogen deposition (linked to 7 in Table 8), and hedgerow shape (for example whether scalloped edges or outgrowths of brambles or blackthorn suckers are present).

As noted in 2.3, further attributes exist which reflect the capacity of hedgerows to have positive impacts on the biodiversity of surrounding habitats and landscape features. These include the export of pollinator services, the export of natural enemies, their hydrological role in water interception and percolation into the soil, and improvements to aquatic environments through removal of pollutants. Since they do not relate to the favourable condition of hedgerows *per se* they are not developed further here – in any event, no thresholds currently exist for them.

In addition, hedgerows provide vital complementary resources for many animals that are dependent on more than one habitat to complete their life cycle. Examples include many insects and birds that breed elsewhere but forage within hedgerows. It is probable that the conditions required by these animals are covered by the thresholds set for other attributes, as given in Tables 7 and 8.

Patch size

There is no optimal length for individual hedgerows given that they are linear features that typically form networks.

Quality of habitat patches

In line with other priority habitats, at least 95% of hedgerows, at an individual or landscape scale as appropriate, should meet the structural, functional and other requirements described above.

Threatened species

All species partially or wholly dependent on this habitat should be Least Concern, when assessed using IUCN criteria (or considered to be Least Concern if not formally assessed), as regards to this habitat.

Ten species have previously (Section 3.1) been chosen as exemplars of threatened species closely associated with hedgerows. These were selected to cover both a wide range of taxonomic groups, and a wide range of habitat requirements. The main current and future threats to them, relating to hedgerows, have been given.

With the exception of unpredictable climate change effects, the thresholds for the 15 attributes listed above are likely, if met, to provide favourable conditions for these ten species, even though the reasons for decline of some are not fully understood: indeed, in the case of the lackey moth wholly unknown. It must be noted that none of the species concerned are dependent on hedgerows alone – achieving FCS will depend on measures being taken in other habitats too. However, as far as the resources provided by hedgerows are concerned, if the given thresholds are met, the species are likely to become Least Concern using IUCN criteria.

Table 9 below gives a brief analysis of the main attributes considered likely to have an impact on the ten threatened species. An X within the table indicates an attribute that is likely to have a beneficial impact on the species. U indicates that an attribute may have an impact but whether there is an impact is uncertain. Cells are left blank where no impact is considered likely.

Table 9 Assessment of which of the 14 favourable condition attributes are likely to play a significant role in meeting the requirements of the ten threatened species exemplars

Species	Size	Gaps	Undisturbed ground	Herbaceous vegetation	Non-native species	Nutrient enrichment	Number of structural components	Structural variation	Connectivity	Plant species richness	Standard trees	Flowers/ fruits	Pesticides	Water stress	Invasive pests & diseases	Dead/ decaying wood
Copse bindweed			x	x	x	x		x					x			
Orange-fruited elm lichen						x					x			x	x	
Brown hairstreak butterfly	x						x	x			x		x			
Pale shining brown moth									x		x		x	x		

Species	Size	Gaps	Undisturbed ground	Herbaceous vegetation	Non-native species	Nutrient enrichment	Number of structural components	Structural variation	Connectivity	Plant species richness	Standard trees	Flowers/ fruits	Pesticides	Water stress	Invasive pests & diseases	Dead/ decaying wood
Lackey moth	U			U		U	U			U			x			
Turtle dove	x		x	x		x	x	x		x			x			
Marsh tit		x							x							
Barbastelle	x	x					U	x	x		U			x		
Hedgehog	x	x	x	x	x		x		x	x			x			x
Hazel dormouse	x	x	x	x			x	x	x	x			x		x	

Monitoring the quality of hedgerows will require a range of approaches, some covered under monitoring in Section 4.1. The hedgerow condition attributes in Table 7 were monitored under Countryside Survey 2007. Countryside Survey methods could also provide data to monitor plant species richness (attribute 10 in Table 8) and hedgerow tree numbers, diversity and age (attribute 11). Pesticide levels (attribute 13) can be monitored in an appropriate sample of hedgerows (vegetation and soils) using standard methods for detecting their chemical presence, linked to research on their known impact on the behaviour or mortality of both target and non-target organisms. The presence of invasive pests and diseases (attribute 15) at a landscape level will normally be picked up through national surveillance schemes (for example, Forest Research programmes), though the impact of these may require further monitoring. Both structural diversity of hedges across network and connectivity (attributes 8 and 9 respectively) might be assessed by developments in earth observation (see discussion under monitoring in Section 4.1). Availability of flowers and fruit (attribute 12) have been assessed using field surveys for research purposes, but this would be labour intensive for national surveys, partly as the time of year is critical for collecting accurate data. A proxy measure that might be used is frequency and severity of hedgerow trimming.

References

Alexander, K. N. A., Bengtsson, B. J., Jansson, N., and Smith, J. P. 2016. *The role of trees outside woodlands in providing habitat and ecological networks for saproxylic invertebrates*. Natural England Commissioned Report NECR225a. http://publications.naturalengland.org.uk/publication/4828234842112000(Accessed 25 March 2024).

Amy, S. R., Heard, M. S., Hartley, S. E., George, C. T., Pywell, R. F., and Staley, J. T. 2015. Hedgerow rejuvenation management affects invertebrate communities through changes to habitat structure. *Basic and Applied Ecology* 16**,** 443 - 451.

Arnold, G. 1983. The influence of ditch and hedgerow structure, length of hedgerow and area of woodland and garden on bird numbers on farmland. *Journal of Applied Ecology* 20, 731-750.

Atkins, E. 2019. Biodiversity value of urban hedges. *In*: J.W. DOVER, ed. *The Ecology of Hedgerows and Field Margins,* 263 -272. Routledge, Abingdon, UK.

Barr, C. J., Britt, C. P., Sparks, T. H., and Churchward, J. M. 2005. *Hedgerow Management and Wildlife: A review of research on the effects of hedgerow management and adjacent land on biodiversity*. Contract report to Defra. 113pp.

Barr, C. J., and Norton, L. R. 2009. *Reporting on hedgerow HAP targets using Countryside Survey 2007 data*. Hedgerow Steering Group paper HSG108. Unpublished.

Barr, C. J., Stuart, R. C., Smart, S. M., and Firbank, L. G. 1999. *Results from MAFF-funded work in the CS2000 programme.* https://countrysidesurvey.org.uk/sites/default/files/M03_hedgerows_final_report.pdf (Accessed 25 March 2024).

Bellamy, P. E., and Hinsley, S. A. 2005. The role of hedgerows in linking woodland bird populations. *In*: *Planning, people and practice: the landscape ecology of sustainable landscapes. Proceedings of the 13th Annual IALE (UK) Conference*, 99-106.

Besnard, A.G., and Secondi, J. 2014. Hedgerows diminish the value of meadows for grassland birds: Potential conflicts for agri-environment schemes. *Agriculture, Ecosystems and Environment* 189, 21-27.

Bosanquet, S. D. S., Ainsworth, A. M., Cooch, S. P., Genney, D. R., and Wilkins, T. C. 2018. *Guidelines for the Selection of Biological SSSIs. Part 2: Detailed Guidelines for Habitats and Species Groups. Chapter 14 Non-lichenised Fungi*. Joint Nature Conservation Committee, Peterborough.

Botías, C., Basley, K., Nicholls, E., and Goulson, D. 2019. Impact of pesticide use on flora and fauna of field margins and hedgerows. *In*: J.W. Dover, (ed). *The Ecology of Hedgerows and Field Margins*, 90-109. Routledge, Abingdon, UK.

Breed, M. F., Ottewell, K. M., Gardner, M. G., and Lowe, A. J. 2011. Clarifying climate change adaptation responses for scattered trees in modified landscapes. *Journal of Applied Ecology* 48, 637-641.

Brewer, A., Ditchburn, B., Cross, D., Whitton, E., and Ward, A. 2019. *Tree cover outside woodland in Great Britain*. National Forest Inventory, Statistical Report. Forestry Commission.

Bright, P. W. 1998. Behaviour of specialist species in habitat corridors: Arboreal dormice avoid corridor gaps. *Animal Behaviour* 56**,** 1485-1490.

Bright, P. W., and MacPherson, D. 2002. Hedgerow management, dormice and biodiversity. *English Nature Research Report 454*. Natural England, Peterborough.

Broughton, R. K., and Hinsley, S. A. 2015. The ecology and conservation of the Marsh Tit in Britain. *British Birds* 108, 12-29.

Brown, M. J., Bunce, R. G. H., Carey, P. D., Chandler, K., Crowe, A., Maskell, L. C., Norton, L. R., Scott, R. J., Scott, W. A., Smart, S. M., Stuart, R. C., Wood, C. M., Wright, S. M. 2016. *Landscape linear feature data 2007 [Countryside Survey].* NERC Environmental Information Data Centre. (Dataset). https://doi.org/10.5285/e1d31245-4c0a-4dee-b36c-b23f1a697f88 (Accessed 25 March 2024).

Browne, S. J., Aebischer, N. J., Yfantis, G., and Marchant, J. H. 2004. Habitat availability and use by turtle doves *Streptopelia turtur* between 1965 and 1995: An analysis of common birds census data. *Bird Study* 51, 1-11.

Bunce, R. G. H., Barr, C. J., Gillespie, M. K., and Howard, D. C. 1996. The ITE Land Classification: providing an environmental stratification of Great Britain. *Environmental Monitoring and Assessment* 39, 39-46.

Bunce, R. G. H., Carey, P. D., Maskell, L. C., Norton, L. R., Scott, R. J., Smart, S. M., and Wood, C. M. *Countryside Survey 2007 vegetation plot data* https://doi.org/10.5285/57f97915-8ff1-473b-8c77-2564cbd747bc (Accessed 27 Jan 2020).

Burel, F., and Baudry, J. 2012. Hedgerow connectivity. pp 75-86. In Dover, J.W. (Ed.) *Hedgerow Futures: Proceedings of the first International Hedgelink Conference*, September 2012, Stoke-on-Trent.

Carey, P. D., Wallis, S., Chamberlain, P. M., Cooper, A., Emmett, B. A., Maskell, L. C., McCann, T., Murphy, J., Norton, L. R., Reynolds, B., Scott, W. A., Simpson, I. C., Smart, S. M., and Ullyett, J. M. 2008. *Countryside Survey: UK Results from 2007*. NERC/Centre for Ecology & Hydrology, 105pp. (CEH Project Number: C03259).

Carey, P. D., Wallis, S., Emmett, B. A., Maskell, L. C., Murphy, J., Norton, L. R., Simpson, I. C., and Smart, S. M. 2008a. *Countryside Survey: UK Headline Messages from 2007*. NERC/Centre for Ecology & Hydrology, 30pp. (CEH Project Number: C03259).

Carrasco, L., Norton, L., Henrys, P., Siriwardena, G. M., Rhodes, C. J., Rowland, C., and Morton, D. 2018. Habitat diversity and structure regulate British bird richness: Implications of non-linear relationships for conservation. *Biological Conservation* 226, 256–263.

Clements, D. K., and Alexander, K. N. A. 2009. A comparative study of the invertebrate faunas of hedgerows of differing ages, with particular reference to indicators of ancient woodland and ‘old growth’. *The Journal of Practical Ecology and Conservation* 8, 7−27.

Committee on Climate Change. 2019. *Net Zero - the UK's contribution to stopping global warming*. www.theccc.org.uk/publication/net-zero-the-uks-contribution-to-stopping-global-warming/ (Accessed 25 March 2024).

Concepción, E. D., Díaz, M., Kleijn, D., Báldi, A., Batáry, P., Clough, Y., Gabriel, D., Herzog, F., Holzschuh, A., Knop, E., Marshall, E. J. P., Tscharntke, T., and Verhulst, J. 2012. Interactive effects of landscape context constrain the effectiveness of local agri-environmental management. *Journal of Applied Ecology* 49, 695-705.

Cooper, A., McCann, T., and Rogers, D. 2009. Northern Ireland Countryside Survey 2007: Broad Habitat Change 19982007. *Northern Ireland Environment Agency Research and Development Series* No. 09/06.

Coppins, A. M. 2001. Wayside trees, hedgerows and shrubs. *In*: A. Fletcher, (ed.). *Lichen Habitat Management*. London: British Lichen Society.

Coulthard, E. J. 2012. Do moths use hedgerows as flight paths? An investigation of the use of linear boundary features by macro moths in intensive agricultural landscapes. *In*: J.W. Dover, (ed.). *Hedgerow Futures: Proceedings of the first International Hedgelink Conference, September 2012, Stoke-on-Trent*, 91-97.

Countryside Survey. 2009: *England Results from 2007*. NERC/Centre for Ecology and Hydrology, Department for Environment, Food and Rural Affairs, Natural England, 119pp. CEH Project Number: C03259.

Cowan, A., and Crompton, R. M. 2004. Bats in the United Kingdom, a landscape scale perspective: considering the importance of habitat connectivity and the threats posed by fragmentation. *In:* R. Smithers (ed.). *Landscape Ecology of Trees and Forests: proceedings of the twelfth annual IALE (UK) conference, held at the Royal Agricultural College, Cirencester, 21st-24th June 2004*, 301-306.

Cranmer, L., McCollin, D., and Ollerton, J. 2012. Landscape structure influences pollinator movements and directly affects plant reproductive success. *Oikos* 121, 562-568.

Critchley, C. N. R., Wilson, L. A., Mole, A. C., Astbury, S. S., and Bhogal, A. 2010. *Restoration of Herbaceous Hedgerow Flora: Review and Analysis of Ecological Factors and Restoration Techniques. Phase 1.* Final report for Defra project BD5301.

Critchley, C. N. R., Wilson, L. A., Mole, A. C., Norton, L. R., and Smart, S. M. 2013. A functional classification of herbaceous hedgerow vegetation for setting restoration objectives. *Biodiversity Conservation* 22, 701–717.

Crosher, I., Gold, S., Heaver, M., Heydon, M., Moore, L., Panks, S., Scott, S., Stone, D., and White, N. 2019a. *The Biodiversity Metric 2.0: Auditing and accounting for biodiversity value. User guide* (Beta Version, July 2019). Natural England Joint Publication JP029. ISBN 978-1-78354-537-7 http://publications.naturalengland.org.uk/publication/5850908674228224 (Accessed 25 March 2024).

Crosher, I., Gold, S., Heaver, M., Heydon, M., Moore, L., Panks, S., Scott, S., Stone, D., and White, N. 2019b. *The Biodiversity Metric 2.0: Auditing and accounting for biodiversity value. Technical supplement* (Beta Version, July 2019). Natural England Joint Publication JP029. ISBN 978-1-78354-538-4 http://publications.naturalengland.org.uk/publication/5850908674228224 (Accessed 25 March 2024).

Davies, Z., and Pullin, A. 2007. Are hedgerows effective corridors between fragments of woodland habitat? An evidence-based approach. *Landscape Ecology* 22**,** 333-351.

DEFRA (Department for Environment, Food and Rural Affairs). 2007. *Hedgerow Survey Handbook: A standard procedure for local surveys in the UK.* 2nd edition. Department for Environment, Food and Rural Affairs.

DEFRA (Department for Environment, Food and Rural Affairs). 2018. *Tree Health Resilience Strategy.* Tree health resilience strategy 2018 - GOV.UK (www.gov.uk) (Accessed 25 March 2024).

Devon County Council, and The Devon Hedge Group. 1997. *Devon's hedges: conservation and management*. Devon Books, Tiverton, Devon.

Dicks, L. V., Baude, M., Roberts, S. P. M., Phillips, J., Green, M., and Carvell, C. 2015. How much flower-rich habitat is enough for wild pollinators? Answering a key policy question with incomplete knowledge. *Ecological Entomology* 40, 22-35.

Dirkmaat, J. 2012. *Beautiful Europe*. Association for the Dutch Cultural Landscape.

Dover, J. W. 2019. Introduction to hedgerows and field margins. *In:* J.W. Dover, (ed.). *The Ecology of Hedgerows and Field Margins,* 1-34. Routledge, Abingdon, UK.

Dover, J., and Sparks, T. 2000. A review of the ecology of butterflies in British hedgerows. *Journal of Environmental Management* 60**,** 51-63.

Dover, J., Sparks, T., Clarke, S., Gobbett, K., and Glossop, S. 2000. Linear features and butterflies: the importance of green lanes. *Agriculture, Ecosystems and Environment*, 80, 227−242.

Dunn, J. C., and Morris, A. J. 2012. Which features of UK farmland are important in retaining territories of the rapidly declining turtle dove *Streptopelia turtur*? *Bird Study* 59, 394-402.

Evans, D. M., Pocock, M. J. O, Brooks, J., and Memmott, J. 2011. Seeds in farmland food-webs: Resource importance, distribution and the impacts of farm management. *Biological Conservation* 144, 2941-2950.

Evans, D. M., Pocock, M. J. O, Brooks, J., and Memmott, J. 2013. The robustness of a network of ecological networks to habitat loss. *Ecology Letters* 16, 844-852.

Feber, R. 2017. *The role of trees outside woods in contributing to the ecological connectivity and functioning of landscapes*. Woodland Trust Research Report. www.woodlandtrust.org.uk/publications/2017/08/role-of-trees-outside-woods/ (Accessed 25 March 2024).

Feber, R. E., Johnson, P. J., Gelling, M., and MacDonald, D. W. 2019. Ecology and conservation of mammals of hedgerows and field margins. *In:* J.W. Dover, (ed.). *The Ecology of Hedgerows and Field Margins*, 233-249. Routledge, Abingdon, UK.

Forestry Commission. 1951. *Census report no.2. Hedgerow and park timber and woods under five acres.* HMSO, London.

Forest Research. 2009. *Trends, long term survival and ecological values of hedgerow trees: development of populations models to inform strategy.* Defra Research Report BD2111. General enquiries on this form should be made to: (hedgelink.org.uk) (Accessed 25 March 2024).

Fox, R., and Dennis, E., Brown, A., and Curson, J. 2022. A revised Red List of British butterflies. *Insect Conservation and Diversity*. 15. 10.1111/icad.12582.

Fox, R., Brereton, T., Asher, J., August, T. A., Botham, M. S., Bourn, N. A. D., Cruickshanks, K. L., Bulman, C. R., Ellis, S., Harrower, C. A., Middlebrook, I., Noble, D. G., Powney, G. D., Randle, Z., Warren, M. S., and Roy, D. B. 2015. *The State of the UK's Butterflies 2015*. Butterfly Conservation and Centre for Ecology and Hydrology, Butterfly Conservation, Wareham, Dorset, UK.

French, D. D., and Cummins, R. P. 2001. Classification, composition, richness and diversity of British hedgerows. *Applied Vegetation Science* 4, 213-228.

Frey-Ehrenbold, A., Bontadina, F., Arlettaz, R., and Obrist, M. K. 2013. Landscape connectivity, habitat structure and activity of bat guilds in farmland-dominated matrices. *Journal of Applied Ecology* 50, 252-261.

Fuller, R. J., Chamberlain, D. E., Burton, N. H. K., and Gough, S. J. 2001. Distributions of birds in lowland agricultural landscapes of England and Wales: How distinctive are bird communities of hedgerows and woodland? *Agriculture, Ecosystems and Environment,* 84, 79-92.

FWAG South-West. 2017. *Hedgerow Trees*. Advice leaflet. https://www.fwagsw.org.uk/news/hedgerow-trees-advice (Accessed 25 March 2024).

Garbutt, R. A., and Sparks, T. H. 2002. Changes in the botanical diversity of a species rich ancient hedgerow between two surveys (1971-1998). *Biological Conservation* 106, 273-278.

García, A. F., Griffiths, G. J. K., and Thomas, C. F. 2000. Density, distribution and dispersal of the carabid beetle *Nebria brevicollis* in two adjacent cereal fields. *Annals of Applied Biology* 137**,** 89-97.

Garratt, M. P. D., Senapathi, D., Coston, D. J., Mortimer, S. R., and Potts, S. G. 2017. The benefits of hedgerows for pollinators and natural enemies depends on hedge quality and landscape context. *Agriculture, Ecosystems and Environment* 247, 363-370.

Gelling, M., MacDonald, D. W., and Mathews, F. 2007. Are hedgerows the route to increased farmland small mammal density? Use of hedgerows in British pastoral habitats. *Landscape Ecology* 22, 1019-1032.

Goodwin, C. E. D., Hodgson, D. J., Al-Fulaij, N., Bailey, S., Langton, S., and MacDonald, R. A. 2017. Voluntary recording scheme reveals ongoing decline in the United Kingdom hazel dormouse *Muscardinus avellanarius* population. *Mammal Review* 47(3), 183-197.

Goodwin, C. E. D., Suggitt, A. J., Bennie, J., Silk, M. J., Duffy, J. P., Al-Fulaij, N., Bailey, S., Hodgson, D. J., and McDonald, R. A. 2018. Climate, landscape, habitat, and woodland management associations with hazel dormouse *Muscardinus avellanarius* population status. *Mammal Review* 48 (3), 209-223.

Graham, L., Gaulton, R., Gerard, F., and Staley, J. T. 2018. The influence of hedgerow structural condition on wildlife habitat provision in farmed landscapes. *Biological Conservation* 220**,** 122-131.

Green, R. E., Osborne, P. E., and Sears, E. J. 1994. The distribution of passerine birds in hedgerows during the breeding season in relation to characteristics of the hedgerow and adjacent farmland. *Journal of Applied Ecology* 31, 677-692.

Grubisic, M., Van Grunsven, R. H. A., Kyba, C. C. M., Manfrin, A., and Hölker, F. 2018. Insect declines and agroecosystems: does light pollution matter? *Annals of Applied Biology* 173, 180-189.

Haigh, A., O’Riordan, R. M., and Butler, F. 2012. Nesting behaviour and seasonal body mass changes in a rural Irish population of the Western hedgehog (*Erinaceus europaeus*). *Acta Theriologica* 57, 321–331.

Hayhow D. B., Eaton, M. A., Stanbury, A. J., Burns F., Kirby, W. B., Bailey, N., Beckmann, B., Bedford, J., Boersch-Supan, P. H., Coomber, F., Dennis, E. B., Dolman, S. J., Dunn, E., Hall, J., Harrower, C., Hatfield, J. H., Hawley, J., Haysom, K., Hughes, J., Johns, D. G., Mathews, F., McQuatters-Gollop, A., Noble, D. G., Outhwaite, C. L., Pearce-Higgins, J.

W., Pescott, O. L., Powney, G. D., and Symes, N. 2019. *The State of Nature 2019.* The State of Nature partnership. https://nbn.org.uk/wp-content/uploads/2019/09/State-of-Nature-2019-UK-full-report.pdf (Accessed 25 March 2024).

Hinsley, S. A., and Bellamy, P. E. 2019. Birds of hedgerows and other field boundaries. *In*: J.W. Dover, (ed.). *The Ecology of Hedgerows and Field Margins*, 210-232. Routledge, Abingdon, UK.

Hinsley, S. A., and Bellamy, P. E. 2000. The influence of hedge structure, management and landscape context on the value of hedgerows to birds: A review. *Journal of Environmental Management,* 60**,** 33-49.

Hof, A. R., and Bright, P. W. 2010. The value of agri-environment schemes for macroinvertebrate feeders: hedgehogs on arable farms in Britain. *Animal Conservation,* 13, 467-473.

Holden, J., Grayson, R. P., Berdeni, D., Bird, S., Chapman, P. J., Edmondson, J. L., Firbank, L. G., Helgason, T., Hodson, M. E., Hunt, S. F. P., and Jones, D. T. 2019. The role of hedgerows in soil functioning within agricultural landscapes. *Agriculture, Ecosystems & Environment*, *273*, 1-12.

Huntingdon Surveys and Consultants LTD. 1986. *Monitoring Landscape Change*. Huntingdon Surveys and Consultants Ltd, Borehamwood, UK.

Jefferson, R. G. 2004. Insects and fleshy fruits. *British Wildlife*, 16, 95-103.

JNCC. 2007. UK BAP Priority Habitats. https://jncc.gov.uk/our-work/uk-bap-priority-habitats/#list-of-uk-bap-priority-habitats. (Accessed 25 March 2024).

Jongman, R. H. G., and Bunce, R. G. H. 2009. Farmland features in the European Union. A description and pilot inventory of their distribution. *Alterra Report 1936*. Alterra.

Kirby, K. 1995. Rebuilding the English countryside: habitat fragmentation and wildlife corridors as issues in practical conservation. *English Nature Science* report no. 10. English Nature, Peterborough.

Kirby, K. 2018. *Definition of Favourable Conservation Status for lowland mixed deciduous woodland priority habitat.* Natural England Evidence Project Report. In Preparation. http://publications.naturalengland.org.uk/category/5415044475256832 (Accessed 25 March 2024).

Kremen, C., Albrecht, M., and Ponisio, L. 2019. Restoring pollinator communities and pollination services in hedgerows in intensively managed agricultural landscapes. *In:* J.W. Dover, (ed.). *The Ecology of Hedgerows and Field Margins,*163-185. Routledge, Abingdon, UK.

Lack, P.C. 1987. The effects of severe hedge cutting on a breeding bird population. *Bird Study* 34, 139-146.

Lack, P.C. 1988. Hedge intersections and breeding bird distribution in farmland. *Bird Study* 35, 133-136.

Lawton, J. H., Brotherton, P. N. M., Brown, V. K., Elphick, C., Fitter, A. H., Forshaw, J., Haddow, R. W., Hilborne, S., Leafe, R. N., Mace, G. M., Southgate, M. P., Sutherland, W. A., Tew, T. E., Varley, J., and Wynne, G. R. 2010. *Making Space for Nature: a review of England's wildlife sites and ecological network*. Report to Defra. Department for Environment, Food and Rural Affairs, London.

Maddock, A., (ed.). 2008. *UK Biodiversity Action Plan; Priority Habitat Descriptions*. BRIG. https://jncc.gov.uk/our-work/uk-bap-priority-habitats/. (Accessed 26 March 2024). This description follows advice given by the Steering Group for the UK Biodiversity Action Plan for Hedgerows (now Hedgelink).

Maudsley, M., Seeley, B., and Lewis, O. 2002. Spatial distribution patterns of predatory arthropods within an English hedgerow in early winter in relation to habitat variables. *Agriculture Ecosystems and Environment* 89, 77-89.

Manning, A. D., Gibbons, P., and Lindenmayer, D. B. 2009. Scattered trees: a complementary strategy for facilitating adaptive responses to climate change in modified landscapes? *Journal of Applied Ecology* 46, 915-919.

Maskell, L., Henrys, P., Norton, L., Smart, S., and Wood, C. 2013. Distribution of ash trees (*Fraxinus excelsior*) in Countryside Survey data. www.countrysidesurvey.org.uk/sites/default/files/Distribution%20of%20Ash%20trees%20in%20CS_9thJan2013.pdf (Accessed 25 March 2024).

Mathews, F., Kubasiewicz, L. M., Gurnell, J., Harrower, C.A., McDonald, R. A., and shore, R.F. 2018. *A Review of the Population and Conservation Status of British Mammals.* A report by the Mammal Society under contract to Natural England, Natural Resources Wales and Scottish Natural Heritage. Peterborough: Natural England.

Mathews, F., Lovett, L., Rushton, S., and MacDonald, D. W. 2006. Bovine tuberculosis in cattle: reduced risk on wildlife-friendly farms. *Biology Letters* 2, 271-274.

Merckx, T., and Berwaerts, K. 2010. What type of hedgerows do Brown hairstreak (*Thecla betulae* L.) butterflies prefer? Implications for European agricultural landscape conservation. *Insect Conservation and Diversity* 3, 194-204.

Merckx, T., Feber, R. E., McLaughlan, C., Bourn, N. A. D., Parsons, M. S., Townsend, M. C., Riordan, P., and MacDonald, D. W. 2010a. Shelter benefits less mobile moth species: the field-scale effect of hedgerow trees. *Agriculture, Ecosystems and Environment* 138**,** 147-151.

Merckx, T., Feber, R., Parsons, M., Bourn, N., Townsend, M., Riordan, P., and MacDonald, D.W. 2010b. Habitat preference and mobility of *Polia bombycina*: are non-tailored agri-environment schemes any good for a rare and localised species? *Journal of Insect Conservation* 14, 499–510.

Merckx, T., Feber, R. E, Riordan, P., Townsend, M. C., Bourn, N. A. D., Parsons, M. S., and MacDonald, D. W. 2009. Optimizing the biodiversity gain from agri-environment schemes. *Agriculture, Ecosystems and Environment* 130**,** 177-182.

Merckx, T., Marini, L., Feber, R. E., and MacDonald, D. W. 2012. Hedgerow trees and extended-width field margins enhance macro-moth diversity: implications for management. *Journal of Applied Ecology* 49, 1396-1404.

Mitchell, R. J., Bailey, S., Beaton, J. K., Bellamy, P. E., Brooker, R. W., Broome, A., Chetcuti, J., Eaton, S., Ellis, C. J., Farren, J., Gimona, A., Goldberg, E., Hall, J., Harmer, R., Hester, A. J., Hewison, R. L., Hodgetts, N. G., Hooper, R. J., Howe, L., Iason, G. R., Kerr, G., Littlewood, N. A., Morgan, V., Newey, S., Potts, J. M., Pozsgai, G., Ray, D., Sim, D. A., Stockan, J. A., Taylor, A. F. S., and Woodward, S. 2014. Ash dieback in the UK: A review of the ecological and conservation implications and potential management options. *Biological Conservation* 175, 95–109.

Moorhouse, T. P., Palmer, S. C. F., Travis, J. M. J., and MacDonald, D. W. 2014. Hugging the hedges: Might agri-environment manipulations affect landscape permeability for hedgehogs? *Biological Conservation* 176, 109-116.

Morris, K. 2021. Definition of Favourable Conservation Status for Hazel or Common dormouse, *Muscardinus avellanarius.* Natural England.

Müller, G. 2013. *Europe's Field Boundaries*. Two volumes. Stuttgart: Neuer Kunstverlag.

Natural England. 2009. *Agri-environment schemes in England 2009: a review of results and effectiveness.* http://publications.naturalengland.org.uk/publication/46002 (Accessed 25 March 2024).

Pollard, E., Hopper, M. D., and Moore, N. W. 1974. *Hedges*. The New Naturalist 58. London: William Collins and Sons Ltd.

Potter, C., and Lobley, M. 1996. *Processes of Countryside Change in Britain*. Report for the Department of Environment.

Rackham, O. 1986. *The History of the Countryside*. London: J.M Dent & Sons.

Rackham, O. 1994. *The Illustrated History of the Countryside*. George Weidenfeld and Nicholson Ltd.

Randle, Z., Evans-Hill, L. J., and Fox, R. 2019. *Atlas of Britain and Ireland's Larger Moths*. Newbury: Pisces Publications.

Rappaport, D. I., Tambosi, L. R., and Metzger, J. P. 2015. A landscape triage approach: combining spatial and temporal dynamics to prioritize restoration and conservation. *Journal of Applied Ecology* 52, 590-601.

Raskin, B., and Osborn, S. 2019. *The agroforestry handbook*. Bristol: Soil Association.

Redhead, J. W., Coombes, C. F., Dean, H. J., Dyer, R., Oliver, T., Pocock, M. J. O., Rorke, S. J., Vanbergen, A. J., Woodcock, B. A., and Pywell, R. F. 2018. *Plant pollinator interactions for potential networks.* Environmental Information Data Centre. https://catalogue.ceh.ac.uk/documents/6d8d5cb5-bd54-4da7-903a-15bd4bbd531b (Accessed 25 March 2024).

Sarlöv Herlin, I. L., and Fry, G. L. A. 2000. Dispersal of woody plants in forest edges and hedgerows in a southern Swedish agricultural area: The role of site and landscape structure. *Landscape Ecology* 15, 229−242.

Scheper, J., Holzschuh, A., Kuussaari, M., Potts, S. G., Rundlof, M., Smith, H. G., and Kleijn, D. 2013. Environmental factors driving the effectiveness of European agri-environmental measures in mitigating pollinator loss--a meta-analysis. *Ecology Letters* 16, 912-920.

Scholefield, P., Morton, D., Rowland, C., Henrys, P., Howard, D., and Norton, L. 2016. A model of the extent and distribution of woody linear features in rural Great Britain. *Ecology and Evolution* 6, 8893-8902.

Slade, E. M., Merckx, T., Riutta, T., Bebber, D. P., Redhead, D., Riordan, P., and MacDonald, D. W. 2013. Life-history traits and landscape characteristics predict macro-moth responses to forest fragmentation. *Ecology* 94, 1519-1530.

Smart, S. M., Bunce, R. G. H., Firbank, L. G., and Coward, P. 2002. Do field boundaries act as refugia for grassland plant species diversity in Britain? *Agriculture, Ecology and Environment* 91, 73-87.

Smart, S. M., Bunce, R. G. H., and Stuart, R. C. 2001. An assessment of the potential of British hedges to act as corridors and refuges for Ancient Woodland Indicator plants. *In*: C. BARR & S. PETIT eds. *Hedgerows of the world: their ecological functions in different landscapes.* International Association for Landscape Ecology (UK).

Smart, S. M., Le Duc, M., Marrs, R. H., Rossall, M. J., Bunce, R. G. H., Thompson, K., and Firbank, L. G. 2006. Spatial relationships between intensive land cover and residual plant species diversity in temperate, farmed landscapes. *Journal of Applied Ecology* 43, 1128-1137.

Spake, R., Bellamy, C., Graham, L. J., Watts, K., Wilson, T., Norton, L. R., Wood, C. M., Schmucki, R., Bullock, J. M., and Eigenbrod, F. 2019. An analytical framework for spatially targeted management of natural capital. *Nature Sustainability* 2, 90-97.

Sparks, T. H., and Martin, T. 1999. Yields of hawthorn *Crataegus monogyna* berries under different hedgerow management. *Agriculture Ecosystems and Environment,* 72**,** 107-110.

Staley, J. T., Adams, N .P., Amy, S. R., Botham, M. S., Chapman, R. E., Hulmes, L., Hulmes, S., Dean, H. J., McCracken, M. E., Mitschunas, N., Peyton, J. M., Savage, J., Ridding, L. E., Baldock, K.S. and Pywell, R. F. 2018. *Effects of hedgerow management and restoration on wildlife*. Final Report to Defra, project BD2114.

Staley, J. T., Amy, S. R., Adams, N. P., Chapman, R. E., Peyton, J. M., and Pywell, R. F. 2015. Re-structuring hedges: rejuvenation management can improve the long term quality of hedgerow habitats for wildlife. *Biological Conservation* 186, 187-196.

Staley, J. T., Amy, S., Facey, S. L. & Pywell, R. F. 2012b. Hedgerow conservation and management: a review of 50 years of applied research in the UK. *In*: J.W. Dover (ed.). *Hedgerow Futures,* 111-133. Published by the Tree Council for Hedgelink, Staffordshire University, Stoke-on-Trent, UK.

Staley, J. T., Botham, M. S., Amy, S. R., Hulmes, S., and Pywell, R. F. 2018. Experimental evidence for optimal hedgerow cutting regimes for Brown hairstreak butterflies. *Insect Conservation and Diversity,* 11, 213-218.

Staley, J. T., Botham, M. S., Chapman, R. E., Amy, S. R., Heard, M. S., Hulmes, L., Savage, J., and Pywell, R. F. 2016. Little and late: how reduced hedgerow cutting can benefit Lepidoptera. *Agriculture, Ecosystems and Environment,* 224, 22–28.

Staley, J. T., Bullock, J. M., Baldock, K. C. R., Redhead, J. W., Hooftman, D. A. P., Button, N., and Pywell, R. F. 2013. Changes in hedgerow floral diversity over 70 years in an English rural landscape, and the impacts of management. *Biological Conservation,* 167, 97-105.

Staley, J. T., Sparks, T. H., Croxton, P. J., Baldock, K. C. R., Heard, M. S., Hulmes, S., Hulmes, L., Peyton, J., Amy, S. R., and Pywell, R. F. 2012a. Long-term effects of hedgerow management policies on resource provision for wildlife. *Biological Conservation,* 145, 24–29.

Stanbury, A. , Brown, A., Eaton, M., Aebischer, N., Gillings, S., Hearn, R., Noble, D., Stroud, D., and Gregory, R. 2017. The risk of extinction for birds in Great Britain. *British Birds* 110, 502-517.

Stuart, R. C., Firbank, L.G., Maskell, L. C., and Smart, S. M. 2005. *Countryside Survey data and favourable condition indicators for ancient and/or species rich hedgerows*. Defra Project Report BD2110. Lancaster: Centre for Ecology and Hydrology.

Van Der Linde, S., Suz, L. M., Orme, C. D. L., Cox, F., Andreae, H., Asi, E., Atkinson, B., Benham, S., Carroll, C., Cools, N., and De Vos, B. 2018. Environment and host as large-scale controls of ectomycorrhizal fungi. *Nature* 558, 243–248.

Westaway, S., and Smith, J. 2019. *Productive hedges: Guidance on bringing Britain's hedges back into the farm business*. The Organic Research Centre, Elm Farm.

Wilson, P. 2019. Botanical diversity in the hedges and field margins of lowland Britain. *In*: J.W. Dover, (ed.). *The Ecology of Hedgerows and Field Margins*, 35-54. Abingdon: Routledge.

Wolton, R. J. 2015. Life in a Hedge. *British Wildlife* 26 (5), 306-316.

Wolton, R. J. 2018. *The Natural Capital of Hedges*. Unpublished briefing note for Hedgelink.

Wolton, R., Adams, N., Ledder, E., Stokes, J., Stratton, J., and Wolton, P. 2010. *Hedgelink visit to the hedges and orchards of Normandy, France, 8-10 May 2010*. Unpublished Hedgelink report.

Wolton, R. J., Bentley, H., Chandler, P. J., Drake, C. M., Kramer, J., Plant, A. R., and Stubbs, A. E. 2014b. The diversity of Diptera associated with a British hedge. *Dipterists Digest* 21, 1−36.

Wolton, R. J., Morris, R. K. A., Pollard, K., and Dover J. W. 2013. *Understanding the combined biodiversity benefits of the component features of hedges*. Report of Defra project BD5214.

Wolton, R. J., Pollard, K. A., Goodwin, A., and Norton, L. 2014a. *Regulatory services delivered by hedges: the evidence base*. Report of Defra project LM0106. 99pp.

Wright, J. 2016. *A natural history of the hedgerow and ditches, dykes and stone walls*. London: Profile Books.

Zanden, E. H. Van Der, Verburg, P. H., and Mücher, C. A. 2013. Modelling the spatial distribution of linear landscape elements in Europe. *Ecological Indicators* 27, 125–136.

Zeale, M. R. K., Davidson-Watts, I., and Jones, G. 2012. Home range use and habitat selection by Barbastelle bats (*Barbastella barbastellus*): Implications for conservation. *Journal of Mammology* 93, 1110-1118.

Appendix 1: Threatened Priority Species significantly associated with hedgerows

Table 10 Threatened species significantly associated with hedgerows

All species	Common name	Latin name	IUCN threat category
Vascular plant	Bastard balm	*Melittis melissophyllum*	Vulnerable
Vascular plant	Copse-bindweed	*Fallopia dumetorum*	Vulnerable
Vascular plant	Crested cow-wheat	*Melampyrum cristatum*	Vulnerable
Vascular plant	Grape hyacinth	*Muscari neglectum*	Vulnerable
Vascular plant	Plymouth pear	*Pyrus cordata*	Vulnerable
Vascular plant	Starved wood-sedge	*Carex depauperata*	Endangered
Non-vascular plant	Pale Bristle moss	*Orthotricium pallens*	Not Assessed
Non-vascular plant	Round-leaved feather-moss	*Rhynchostegium rotundifolium*	Not Assessed
Fungi	Sandy stilt puffball fungus	*Battarrea phalloides* (Dicks.) Pers.	Not Assessed (Sch 8)
Fungi	Weathered earthstar fungus	*Geastrum corollinum* (Batsch) Hollós	Not Assessed
Fungi	Pepper pot fungus	*Myriostoma coliforme* (With.) Corda	Not Assessed
Lichen	a lichen	*Anaptychia ciliaris subsp. ciliaris* (L.) Körb. ex A. Massal	Endangered
Lichen	a lichen	*Bacidia incompta* (Borrer) Anzi	Vulnerable
Lichen	a lichen	*Caloplaca flavorubescens*	Endangered
Lichen	Orange-Fruited Elm-lichen	*Caloplaca luteoalba* (Turner) Th. Fr.	Endangered
Lichen	a lichen	*Caloplaca virescens* (Sm.) Coppins	Endangered
Lichen	a lichen	*Cryptolechia carneolutea (Turner) A. Massal.*	Endangered
Lichen	a lichen	*Parmelina quercina* (Willd.) Hale NB British material is *P. carporrhizans*	Vulnerable
Lichen	Southern grey physcia	*Physcia tribacioides* Nyl.	Vulnerable
Lichen	Golden hair-lichen lichen	*Teloschistes flavicans* (Sw.) Norman	Vulnerable
Lichen	A beard lichen (String-of-sausages lichen)	*Usnea articulata* (L.) Hoffm.	Near Threatened

All species	Common name	Latin name	IUCN threat category
Lichen	A beard lichen	*Usnea florida* (L.) Weber ex F.H. Wigg.	Near Threatened
Lichen	a lichen	*Wadeana dendrographa*	Near Threatened
Lichen	a lichen	*Wadeana minuta*	Near Threatened
Beetle	Hazel pot beetle	*Cryptocephalus coryli*	Endangered
Beetle	Six-spotted pot beetle	*Cryptocephalus sexpunctatus*	Endangered
Beetle	Scarlet malachite beetle	*Malachius aeneus*	Near Threatened
Beetle	Alder flea weevil	*Orchestes testaceus*	Vulnerable (pre 94)
Beetle	Cardinal click beetle or Red-horned cardinal click beetle	*Ampedus rufipennis*	Vulnerable (pre 94)
Butterfly	Brown hairstreak	*Thecla betulae*	Vulnerable
Butterfly	White-letter hairstreak	*Satyrium w-album*	Endangered
Moth	Barberry carpet	*Pareulype berberatais*	Endangered
Moth	Heart moth	*Dicycla oo*	Near Threatened
Moth	Pale shining brown	*Polia bombycina*	Endangered
Moth	Scarce vapourer	*Orgyia recens*	Endangered
Moth	Liquorice piercer moth	*Grapholita (Cydia) pallifrontana*	Not Assessed (probably Least Concern, notable)
Moth	Flounced Chestnut	*Agrochola helvola*	Near Threatened
Moth	Beaded Chestnut	*Agrochola lychnidis*	Near Threatened
Moth	Mouse Moth	*Amphipyra tragopoginis*	Vulnerable
Moth	Large Nutmeg	*Apamea anceps*	Near Threatened
Moth	Garden Tiger	*Arctia caja*	Near Threatened
Moth	Sprawler	*Asteroscopus sphinx*	Vulnerable
Moth	Minor Shoulder-knot	*Brachylomia viminalis*	Near Threatened
Moth	Broom-tip	*Chesias rufata*	Near Threatened
Moth	Figure of Eight	*Diloba caeruleocephala*	Endangered
Moth	September Thorn	*Ennomos erosaria*	Near Threatened
Moth	Dusky Thorn	*Ennomos fuscantaria*	Near Threatened
Moth	Autumnal Rustic	*Eugnorisma glareosa*	Near Threatened
Moth	Garden Dart	*Euxoa nigricans*	Vulnerable
Moth	White-line dart	*Euxoa tritici*	Vulnerable
Moth	Double Dart	*Graphiphora augur*	Near Threatened
Moth	Lackey	*Malacosoma neustria*	Vulnerable
Moth	Broom Moth	*Melanchra pisi*	Vulnerable
Moth	Hedge Rustic	*Tholera cespitis*	Vulnerable
Moth	Pale Eggar	*Trichiura crataegi*	Vulnerable
Moth	Oak Hook-tip	*Watsonalla binaria*	Vulnerable
Moth	Dusky-lemon sallow	*Xanthia gilvago*	Near Threatened
Moth	Sallow	*Xanthia icteritia*	Near Threatened
Moth	Dark-barred Twin-spot Carpet	*Xanthorhoe ferrugata*	Near Threatened
Amphibian	Common toad	*Bufo bufo*	Near Threatened
Bird	Grey partridge	*Perdix perdix*	Vulnerable
Bird	Turtle dove	*Streptopelia turtur*	Critically Endangered

All species	Common name	Latin name	IUCN threat category
Bird	Cuckoo	*Cuculus canorus*	Vulnerable
Bird	Lesser spotted woodpecker	*Dryobates minor*	Endangered
Bird	Marsh tit	*Poecile palustris (Parus palustris)*	Vulnerable
Bird	Willow tit	*Poecile montana (Parus montanus)*	Endangered
Bird	Red-backed shrike	*Lanius collurio*	Critically Endangered
Bird	Starling (Common starling)	*Sturna vulgaris*	Vulnerable
Bird	Tree sparrow	*Passer montanus*	Vulnerable
Bird	Greenfinch	*Carduelis chloris*	Endangered
Bird	Linnet (Common linnet)	*Carduelis cannabina*	Near Threatened
Bird	Lesser redpoll (Common Redpoll)	*Acanthis flammea (Carduelis cabaret)*	Vulnerable
Mammal	Barbastelle	*Barbastella barbastellus*	Vulnerable
Mammal	Serotine	*Eptesicus serotinus*	Vulnerable
Mammal	Hedgehog (West European Hedgehog)	*Erinaceus europaeus*	Vulnerable
Mammal	Harvest mouse	*Micromys minutus*	Near Threatened
Mammal	Dormouse (Hazel dormouse)	*Muscardinus avellanarius*	Vulnerable

Appendix 2: NCA name by number (for Table 5, Section 3.1)

Number	NCA name	Number	NCA name
1	North Northumberland Coastal Plain	33	Bowland Fringe and Pendle Hill
2	Northumberland Sandstone Hills	34	Bowland Fells
3	Cheviot Fringe	35	Lancashire Valleys
4	Cheviots	36	Southern Pennines
5	Border Moors and Forests	37	Yorkshire Southern Pennine Fringe
6	Solway Basin	38	Nottinghamshire, Derbyshire and Yorkshire Coalfield
7	West Cumbria Coastal Plain	39	Humberhead Levels
8	Cumbria High Fells	40	Holderness
9	Eden Valley	41	Humber Estuary
10	North Pennines	42	Lincolnshire Coast and Marshes
11	Tyne Gap and Hadrian's Wall	43	Lincolnshire Wolds
12	Mid Northumberland	44	Central Lincolnshire Vale
13	South East Northumberland Coastal Plain	45	Northern Lincolnshire Edge with Coversands
14	Tyne and Wear Lowlands	46	The Fens
15	Durham Magnesian Limestone Plateau	47	Southern Lincolnshire Edge
16	Durham Coalfield Pennine Fringe	48	Trent and Belvoir Vales
17	Orton Fells	49	Sherwood
18	Howgill Fells	50	Derbyshire Peak Fringe and Lower Derwent
19	South Cumbria Low Fells	51	Dark Peak
20	Morecambe Bay Limestones	52	White Peak
21	Yorkshire Dales	53	South West Peak
22	Pennine Dales Fringe	54	Manchester Pennine Fringe
23	Tees Lowlands	55	Manchester Conurbation
24	Vale of Mowbray	56	Lancashire Coal Measures
25	North Yorkshire Moors and Cleveland Hills	57	Sefton Coast
26	Vale of Pickering	58	Merseyside Conurbation
27	Yorkshire Wolds	59	Wirral
28	Vale of York	60	Mersey Valley
29	Howardian Hills	61	Shropshire, Cheshire and Staffordshire Plain
30	Southern Magnesian Limestone	62	Cheshire Sandstone Ridge
31	Morecambe Coast and Lune Estuary	63	Oswestry Uplands
32	Lancashire and Amounderness Plain	64	Potteries and Churnet Valley

Number	NCA name	Number	NCA name
65	Shropshire Hills	102	Teme Valley
66	Mid Severn Sandstone Plateau	103	Malvern Hills
67	Cannock Chase and Cank Wood	104	South Herefordshire and Over Severn
68	Needwood and South Derbyshire Claylands	105	Forest of Dean and Lower Wye
69	Trent Valley Washlands	106	Severn and Avon Vales
70	Melbourne Parklands	107	Cotswolds
71	Leicestershire and South Derbyshire Coalfield	108	Upper Thames Clay Vales
72	Mease/Sence Lowlands	109	Midvale Ridge
73	Charnwood	110	Chilterns
74	Leicestershire and Nottinghamshire Wolds	111	Northern Thames Basin
75	Kesteven Uplands	112	Inner London
76	North West Norfolk	113	North Kent Plain
77	North Norfolk Coast	114	Thames Basin Lowlands
78	Central North Norfolk	115	Thames Valley
79	North East Norfolk and Flegg	116	Berkshire and Marlborough Downs
80	The Broads	117	Avon Vale
81	Greater Thames Estuary	118	Bristol, Avon Valleys and Ridges
82	Suffolk Coast and Heaths	119	North Downs
83	South Norfolk and High Suffolk Claylands	120	Wealden Greensand
84	Mid Norfolk	121	Low Weald
85	Breckland	122	High Weald
86	South Suffolk and North Essex Clayland	123	Romney Marshes
87	East Anglian Chalk	124	Pevensey Levels
88	Bedfordshire and Cambridgeshire Claylands	125	South Downs
89	Northamptonshire Vales	126	South Coast Plain
90	Bedfordshire Greensand Ridge	127	Isle of Wight
91	Yardley-Whittlewood Ridge	128	South Hampshire Lowlands
92	Rockingham Forest	129	Thames Basin Heaths
93	High Leicestershire	130	Hampshire Downs
94	Leicestershire Vales	131	New Forest
95	Northamptonshire Uplands	132	Salisbury Plain and West Wiltshire Downs
96	Dunsmore and Feldon	133	Blackmoor Vale and the Vale of Wardour
97	Arden	134	Dorset Downs and Cranborne Chase
98	Clun and North West Herefordshire Hills	135	Dorset Heaths
99	Black Mountains and Golden Valley	136	South Purbeck
100	Herefordshire Lowlands	137	Isle of Portland
101	Herefordshire Plateau	138	Weymouth Lowlands

Number	NCA name	Number	NCA name
139	Marshwood and Powerstock Vales	150	Dartmoor
140	Yeovil Scarplands	151	South Devon
141	Mendip Hills	152	Cornish Killas
142	Somerset Levels and Moors	153	Bodmin Moor
143	Mid Somerset Hills	154	Hensbarrow
144	Quantock Hills	155	Carnmenellis
145	Exmoor	156	West Penwith
146	Vale of Taunton and Quantock Fringes	157	The Lizard
147	Blackdowns	158	Isles of Scilly
148	Devon Redlands	159	Lundy
149	The Culm		

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