Summary of evidence: Biodiversity

1. General introduction

This summary sets out Natural England's assessment of the evidence relating to Biodiversity. It provides a statement of the current evidence base, presenting:

- what we know (with supporting data and key references);
- areas that are subject to active research and debate; and
- what we do not yet know from the evidence base.

It also provides information on Natural England research and key external research programmes to show how we are seeking to fill gaps.

This summary forms part of a suite of summaries covering all of Natural England's remit. The summaries are not systematic reviews, but enable us to identify areas where the evidence is absent, or complex, conflicting and/or contested. These summaries are for both internal and external use and will be regularly updated as new evidence emerges and more detailed reviews are completed.

2. Introduction to biodiversity summary of evidence

This summary considers all aspects of biodiversity – from ecosystems to genes - and the evidence is organised in three themes:

- Biodiversity resource and natural capital.
- Biodiversity trends, their drivers and impacts.
- Conservation and value of biodiversity.

3. Biodiversity resource and natural capital

We know that:

3.1 Biodiversity is the variety of life on Earth. It includes diversity within species, between species and of habitats and ecosystems, and encompasses the diversity of interactions between different trophic levels.

3.2 England's biodiversity has been strongly influenced by our diverse geology, active processes, such as coastal geomorphology and hydrology, our position as part of an island on the relatively warm and wet western fringe of Europe, and by man's use of the land and seas. Most of England's land area is wholly man-modified, with urban land, arable or pastoral monocultures or forests of non-native species. Much of the remainder is semi-natural (ie altered by lower levels of human activity) and the retention of the biodiversity interest of these areas

generally requires some form of sympathetic land management with low or no inputs of fertilizers or pesticides.

3.3 The UK's National Ecosystem Assessment (2011) identified eight ecosystem types: mountains, moorlands and heaths; semi-natural grasslands; enclosed farmland; woodlands; freshwaters (open waters, wetlands and floodplains); urban; coastal margins; and marine and there are 21 'broad' habitats in the UK (JNCC 2007), which encompass all of England's land and sea area. Within these are 56 'priority' habitats of principal importance for the conservation of biodiversity under section 41 of the Natural Environment and Rural Communities (NERC) Act 2006. Habitat inventories often overlapped, making it difficult to estimate the location and extent of each habitat type. However, a new consolidated Priority Habitats Inventory (PHI) has been created to eliminate this issue and includes new inventories for a number of habitats (see **www.data.gov.uk/dataset/priority-habitats-inventory**).

3.4 Some of England's habitats are of international importance, especially our vegetated shingle features, estuaries and saltmarshes. England's seas are amongst the most diverse in Europe. England has over half of Europe's chalk cliffs, more chalk rivers than any other country in Europe, and 18% of the world's *Calluna* heathlands (Natural England 2008).

3.5 We know the status and distribution of many larger terrestrial species, thanks to a rich legacy of data collected largely by volunteers. We have on-line access to over 90 million species-location records through the National Biodiversity Network (NBN) Gateway, which provides access to a range of types of dataset, from structured distribution atlas surveys and surveillance schemes to casual sightings. Although the data are amongst the best in the world for groups such as birds, mammals, butterflies and vascular plants, the data for other groups (such as lower plants, smaller invertebrate species, soil fauna, fungi, and marine invertebrates) are patchy or, in some cases, non-existent.

3.6 England has populations of at least 55,000 species of animals, plants and fungi, over a thousand requiring special conservation attention (Natural England 2010). Several hundred taxa are endemic to England. Fifty-four species are threatened at a global level, including 12 assessed as critically endangered (Natural England 2010). Two hundred species with populations in England are formally regarded as Threatened or near-Threatened in a European context (though note that the threat status of the majority of taxa has yet to be assessed in a European or Global context). In England, 943 'priority' species are listed as of principal importance for the conservation of biodiversity under s41 of the NERC Act 2006. Many others are formally regarded as Threatened in England (see **www.jncc.defra.gov.uk/page-3408**) under International Union for Conservation of Nature (IUCN) guidelines (see 3.14). Our fauna and flora also include some distinct sub-species, reflecting the island status of the UK and history of colonisation.

3.7 England hosts some outstanding species assemblages of international importance: these include breeding seabirds, wintering gulls, waders and wildfowl; invertebrate communities associated with veteran trees, wood-pastures and parkland, and heathland; grassland fungi (notably the waxcap grassland fungi); and Atlantic ferns, mosses and lichens (Natural England 2010).

3.8 Genetic diversity is critical for Biodiversity in England and for food security. Retaining a diverse genetic stock of native species is essential to all species as an aid to continued adaptation to changing environmental conditions and maintaining population viability. In addition, 303 'Crop Wild

Relatives' in 15 plant families have been identified in the UK, nearly all of which occur in England (Hopkins and Maxted 2011). The genes found in crop wild relatives are likely to play an increasing role in plant breeding in the 21st century.

3.9 Non-native species have become a significant presence in England. There are at least 2648 non-native species present in England. Of these, 1737 have established self-sustaining populations (66%), 818 are not established (31%), and 29 (1%) have populations established inside buildings; the status of the remainder is unknown (Roy *et al.* 2012). Approximately 75% are flowering plants and 15% insects (Hill *et al.* 2005); the majority of established non-natives are terrestrial, with less than 5% from marine or freshwater habitats (Roy *et al.* 2012).

3.10 Biodiversity is a key element of Natural Capital, providing the essential basis for ecosystem service provision. Natural capital is an economic metaphor used to describe the physical and biological resources provided by the earth, with associated implications of the need to use it sustainably for the continued provision of ecosystem services (TEEB 2010). The biodiversity element of England's natural capital provides essential provisioning services (eg food, water, wood); supporting services (eg primary production, nutrient cycling, carbon storage); regulating services (eg water quality, pollination); and cultural services (eg wildlife, wild places) (UK National Ecosystem Assessment 2011).

What we don't know:

3.11 We don't know the extent, location and quality of all priority habitats. This is particularly the case in the marine and freshwater environments. Although the extent of most terrestrial priority habitats are generally well known, survey coverage for some habitats is incomplete or lacking; for example we have no inventory for some broad habitats (rivers and streams; standing open waters and canals; arable and horticultural; and boundary and linear features); for some priority habitats (eg inland rock outcrop and scree). Similarly the National Forest Inventory (coordinated by Forestry Commission) does not distinguish priority woodland types. Accurate estimates of the extents of sand dunes and saltmarsh outside protected areas are lacking (UK National Ecosystem Assessment 2011). For all habitats, our information regarding habitat quality is limited, particularly outside designated sites.

3.12 We do not have a sufficient audit of our species biodiversity. While it is practically impossible to provide a complete audit of biodiversity, examples of what can be done for defined regions are shown by the Biodiversity Audits for Breckland and Broads in East Anglia (Dolman *et al.* 2010, Panter *et al.* 2011). The current lack of information may be significant because the species groups that we know least about, such as fungi, soil biota and several invertebrate groups on land and at sea, are also those that are either potentially vulnerable or those most involved in providing regulatory ecosystem services (UK National Ecosystem Assessment 2011).

3.13 We do not know the levels of genetic diversity that occur in most wild populations, even of our most threatened and vulnerable species. As a result, we have very limited understanding of the frequency of genetic impoverishment within our species of conservation concern and, for species with the smallest populations, the degree of in-breeding depression that might be affecting their viability and hence conservation prospects.

Areas of active research and debate:

3.14 Improving Species Status Reviews. Species Status Reviews are systematic and thorough assessments of the conservation threat status of species against standard criteria based on the

internationally accepted guidelines developed by the International Union for Conservation of Nature (IUCN 2013). These assessments then form the basis of the development of Red Lists of species of conservation concern. There are many gaps in the assessment of English biodiversity, but some progress is being made on updating and undertaking new assessments, such as for the saproxylic beetles (Alexander 2013), to provide the underpinning evidence base for our conservation action.

3.15 Habitat Inventories are being developed and improved. A continuing programme of work is underway to collect and collate information on a range of priority habitats, for which data are lacking, as well as to update and improve existing datasets.

3.16 Prioritising species and habitat conservation effort. There are 943 species of principal concern on section 41 of the NERC Act. The species have been prioritised according to conservation status, and actions necessary for the recovery of each have been categorised as of urgent, high, medium or low priority. Natural England is currently working to refine priorities by embracing threatened species other than those listed on s41 and by identifying those most likely to go extinct in very near future (by 2020) to give them urgent attention.

3.17 Improving species, habitat and ecosystem monitoring. There are over 80 National Schemes and Societies collecting and managing species data; however, many important groups are under-recorded and the use of structured sampling and standard methods varies. There are well established monitoring programmes for protected sites and agri-environment schemes, and Natural England has invested in a series of surveys of priority habitats and is developing national habitat surveillance. Defra and associated agencies recognise the need for improving our capability in monitoring and surveillance and are currently developing a national strategy that will provide an over-arching framework for filling gaps in knowledge, improving standards, data access and to ensure that resources are spent most effectively where they are needed most urgently.

3.18 How to mobilise and present biodiversity information at a local scale, to support local decision making. The NBN gateway is our preferred route to mobilise and provide access to species data at all scales, but further work is needed to ascertain differing local requirements for such data. The Biodiversity Action Reporting System (BARS) maps information on conservation action at local scales and provides an additional important resource for local communities (**www.ukbars.defra.gov.uk/**).

4. Biodiversity trends, their drivers and impacts

What we know:

4.1 Biodiversity loss is a global problem, with the rate of species extinctions currently 100-1000 times the background rate indicated by fossil records, and projected to increase a further ten-fold this century (Pimm *et al.* 1995). The global Convention on Biological Diversity (CBD) target to reduce the rate of biodiversity loss by 2010 was missed and none of the global sub-targets were met (CBD 2010). Nearly 500 species have been lost entirely from England, mostly in the last 200 years (Natural England 2010). These recorded losses may under-estimate the true extinction rate, particularly for less well known groups (Hambler *et al.* 2011). Losses in the past 30 years alone include a global endemic species (Ivell's sea anemone) and several Section 41 priority species (BARS 2009).

4.2 Biodiversity loss is likely to reduce the stability of ecosystems (Hooper *et al.* 2005). Greater biodiversity can also have an important 'insurance' role to play in maintaining ecosystem service provision in the face of the loss of individual species (Yachi & Loreau 1999). In addition, ecosystem

function (plant productivity, for example) may improve with increased numbers of species (Petchey *et al.* 2004; Balvenera *et al.* 2006; Hector & Bagchi 2007).

4.3 There has been mixed success in reversing biodiversity declines in England. Over the last 5-10 years 12 of 31 indicators of biodiversity change (39%) have shown an improvement (including the status of species of European conservation concern, area affected by acidification, and coverage of agri-environment schemes), 12 (39%) showed little or no change and 7 (23%) showed a deterioration (including proportion of Sites of Special Scientific Interest (SSSIs) in favourable condition; populations of breeding farmland birds and butterflies, breeding wetland birds) (Defra 2014).

4.4 There were substantial losses of many habitats during the 19th and 20th centuries in England, and many habitats of conservation importance are thus largely confined to small and isolated fragments, particularly in lowland areas (Lawton *et al.* 2010). The largest twentieth century decline was that of species-rich grasslands, of which 97% were lost between the 1930s and 1980s (Fuller 1987). There have been losses of ancient woodland, and many native woodlands are inappropriately managed (Hopkins & Kirby 2007). Some broad habitat types have increased - for example, the cover of broadleaved and coniferous woodlands since 1947 although such plantings have often been of non-native species.

4.5 Although there have been recent improvements in some habitats many are still in decline, either in extent or quality or both. The 2013 Habitats Directive Article 17 assessment showed a decline between 2007 and 2013 in the number of habitats showing favourable conservation status in England, with declines for more than 50% of terrestrial and coastal habitats. However, 6 of 7 freshwater habitats showed improved status (Defra 2013).

4.6 The main causes of current habitat declines are: direct losses to agricultural intensification, inappropriate management (including the abandonment of traditional practices which formerly maintained them) and pollution (JNCC 2010). For example, nutrient enrichment and reduced management have led to losses of short-stature, stress-tolerant plant species and increases in nutrient-loving tall herbs (Preston *et al.* 2002; Carey *et al.* 2008, Countryside Survey 2009). Nitrogen deposition is detrimental to many uplands (Countryside Survey 2009) and 50% of river stretches are at risk of failing Water Framework Directive quality objectives due to diffuse phosphate pollution (Mainstone *et al.* 2008).

4.7 Fragmentation of habitat patches is also a key driver of declining habitat quality (Hooftman & Bullock 2012). As the habitat becomes more fragmented and isolated, the remaining patches are often more difficult to manage effectively, are subject to edge effects, and become less suitable for species with larger home ranges. The species within them are liable to suffer loss of genetic vigour and be prone to invasion by competitive and non-native species (Fahrig 2003, Lawton *et al.* 2010).

4.8 The structured surveillance of certain species groups (notably vascular plants, birds, butterflies, moths and bats) in England is amongst the best in the world (Burns *et al.* 2013). As a result, we possess excellent information on status and trends in species range and abundance for those groups. Much of this information is gathered through the partnership of volunteer observers from conservation and science Non Governmental Organisations (NGOs) (such as British Trust for Ornithology (BTO), Butterfly Conservation and Bat Conservation Trust) who undertake surveys that have been rigorously designed and are analysed by professional scientists.

4.9 There are ongoing rapid declines of many species (Natural England 2008, Burns *et al.* 2013). Losses have not been confined to rare or range-restricted species: many once abundant and ubiquitous species have declined substantially to the extent that some have become range-restricted, rare or regionally extinct as a consequence. There are many localised extinction events; for example, on average, one species of flowering plant is lost from each English county every two years, with the greatest rates of loss in the south and east (Walker 2003). There have been rapid losses (of more than 50% in the last 25 years) of once common species such as hedgehogs, house sparrows and common toads, and extinction of many species in parts of their former range (Burns *et al.* 2013). The index of farmland bird populations is at about 50% of the level in 1970, with tree sparrows down by 97% and turtle doves down by 85% (Robinson 2010). 93% of habitat specialist butterflies and 76% of all butterflies have declined since the 1970s (Thomas 2010). Overall, across our best-known groups, about a quarter of all species is at historically low levels or significantly threatened (Natural England 2010). In addition, specialist species (those with relatively specific niche requirements) have tended to decline faster than generalists (which occupy broader niches), leading to biotic homogenization and a decline in the variety of England's natural environment (Clavel *et al.* 2011, Ross *et al.* 2012, Carvalheiro *et al.* 2013).

4.10 The most important factors causing species loss are habitat loss (eg to intensive farming and built development) and deterioration (abandonment, inappropriate management), eutrophication, climate change, disease, introduced non-native species, human disturbance, predation due to artificially increased levels of predators and the illegal killing and over-exploitation of species (Natural England 2010). We have a good understanding of the extent to which these factors affect a few of our priority species, broad understanding for others, but for many, the drivers of decline are unknown.

4.11 Genetic issues can be important for the conservation of species with small populations. Species populations are often genetically adapted to the environment in which they occur but in most situations the addition of genetic variation will be beneficial to their long-term viability and survival (Reed 2004). In small, genetically isolated populations, genetic drift and inbreeding can lead to 'inbreeding depression' and reduced fitness (eg in natterjack toads, Rowe & Beebee 2005) and, by extrapolation, to increased extinction risk. In some species, the proportion of breeders within a population can be small enough that in-breeding can occur even in what appear to be relatively large populations (Frankham 1995; Hoarau *et al.* 2005).

4.12 In some situations, translocation into small populations of individuals of the same species, but adapted to different environments, can disrupt genetic adaptation to the local environment and result in reduced fitness; so called out-breeding depression (Höglund 2009).

4.13 Climate change is already having major impacts on species and hence on habitats. Changes include southern species expanding their range northwards and some cold-adapted northern/montane species retreating at the southern limit of their distribution. In addition, there has also been a natural spread of new species into Britain from continental Europe, including the bumblebee *Bombus hypnorum* and many species of *Odonata* including the small red-eyed and willow damselflies (Warren *et al.* 2001; Hickling *et al.* 2005, 2006; Franco 2006; Morecroft *et al.* 2009, Morecroft & Speakman 2013). Not all species are showing expected range changes, eg southern amphibians and reptiles do not appear to be spreading north, presumably due to a lack of available habitat, poor dispersal abilities or barriers to movement (Hickling *et al.* 2006). Habitats are also likely to change as a result of changes in component species communities.

4.14 Invasive non-native species, including pathogens, represent a growing threat to biodiversity. Forty-nine invasive non-native species (INNS) in England are currently thought to be having serious negative ecological impacts (19 marine, 13 freshwater, 16 terrestrial), including muntjac, ruddy duck, harlequin ladybird, signal crayfish and Japanese knotweed (Defra 2013). INNS cost the English economy an estimated £1.3 billion per year (Williams *et al.* 2010). In Europe, approximately ten new species become established each year and there is a rising trend for invertebrates and marine fish introductions (Hulme *et al.* 2009). Island species are particularly prone to the effects of non-native species introductions due to a lack of natural competitors and predators (UNEP 2012). In England, introduced rat species have been eradicated from Lundy to help restore breeding seabird populations (Lock 2006).

What we don't know:

4.15 The recent trends in extent and condition of some priority habitats are unknown, particularly in the marine environment. Marine examples include horse mussel beds, inter-tidal mudflats and mud habitats in deep water; examples on land include montane heaths and willow scrub and upland flushes, fens and swamps. Thus, our knowledge is inadequate to meet our two main reporting requirements: for Biodiversity2020 and the Habitats Directive. In addition, we don't have inventories for most Annex 1 habitats (there is not a complete match with the priority habitat classification) nor do we know comprehensively where Annex 1 features occur on SSSIs or even Special Areas of Conservation (SACs).

4.16 The recent trends of most (c.95%) species (including many priority species) are unknown, particularly for mammals, bryophytes, lichens, algae, fungi and the majority of invertebrates. Improving this situation will require both better mobilisation of existing data, considerable additional surveillance and greater use of analysis and modelling. The UK indicator set does not include any index for soil biodiversity or soil quality.

4.17 We lack basic ecological information for most (at least 90%) species (including many priority species), and we often do not know the causes of current declines. Lack of information hinders conservation efforts because we cannot be certain of the habitat management that species require nor know how to achieve the recovery of declining priority species.

4.18 We know little about how species assemblages relate to priority habitats and ecosystems and how changes in species affect habitats and ecosystems. We need a better understanding of traits and requirements of species, how they interact within ecosystems, and the potential importance of functional diversity for maintaining ecosystem function.

4.19 We are unable to quantify accurately the scale of biodiversity losses attributable to different causes. For example, we are unable to say how much priority habitat has been lost or degraded annually due to inappropriate land management or as a consequence of eutrophication. This limits our ability to identify priorities for conservation action at different spatial scales with regard to the drivers of biodiversity loss.

4.20 We do not understand the effects of cumulative impacts of multiple stressors on biodiversity nor, for most ecosystems, the level of impacts that represent tipping points. Tipping points, at which ecosystems permanently shift to a new state, with fundamental changes to biodiversity and the ecosystem services they provide, may be reached by incremental changes in a single factor or

the interacting effects of multiple factors (Anderson *et al.* 2008, Lenton *et al.* 2008; Convention on Biological Diversity, 2010).

4.21 We know little about how habitats, ecosystems and species assemblages will change as a result of climate change-induced extreme events. Although climate change projections suggest an increase in the frequency of extreme weather events (such as the 2013 floods, the 1976 drought and the 1987 storm) and of major disease outbreaks, we do not know how these will impact on biodiversity and land-use practices, nor what the appropriate conservation response to such events should be.

4.22 We do not know how to prevent the spread of new diseases, such as those caused by *Phytophthora* and *Chalara*, which may have long-term impacts on habitats. Nor do we know enough about the vectors that spread disease, the factors that affect them and the unintended impacts of control measures.

4.23 We do not understand why some non-native species become invasive nor, in most cases, how to control them. The precise factors that facilitate a particular species into becoming invasive are currently unpredictable (Jeschke & Strayer 2006, Parrott *et al.* 2009). Further, our inability to control these species is due to a lack of evidence on their ecology and control techniques, and is further hampered by a lack of legal instruments to enforce quarantine or other control methods.

4.24 For small or reduced populations, we don't know how their genetic diversity will affect their persistence, or which components of genetic diversity are most critical for survival.

Areas of active research and debate:

4.25 Defra-funded research is underway to improve the quality of biodiversity indicators. We cannot carry out detailed surveillance of all components of biodiversity and so we need to rely upon certain measures (eg water quality), or monitoring of certain groups (eg birds and butterflies) as indicators for how biodiversity as a whole is changing. There is continuing debate about how much such indicators are representative of wider biodiversity, and further work is needed on this.

4.26 A number of research projects are underway to improve our knowledge of priority species and habitats; these include Natural England's Species Recovery Programme (SRP) and Defra-funded research. The SRP currently includes projects on field cricket, freshwater pearl mussel, Fisher's estuarine moth, red squirrel and lady slipper orchid (**www.gov.uk/government/organisations/natural-england/about/research**). However, the resource required for targeted monitoring, research to understand the causes of declines and the trialling of solutions is considerable and far exceeds that available.

4.27 Work is underway to improve our knowledge of other species and communities of conservation interest, often using novel techniques. Examples include: metagenetic work on soil fauna and the use of eDNA methods for surveys of Great Crested Newts (Kille 2013), and support for the development of Long-term Monitoring Network (**www.ecn.ac.uk/what-we-do/science/projects/ecbn/ecbn**) to work closely with CEH's Ecological Change Network (Morecroft *et al.* 2009).

4.28 There is debate about which, if any, non-native species we should accept, or even welcome, as new additions to England's biodiversity and which we should actively eradicate. The potential conservation benefits of non-natives includes providing habitat or food resources to rare

species, serving as functional substitutes for extinct taxa, and providing desirable ecosystem functions (Schlaepfer *et al.* 2011). There is also debate about the possibility of the deliberate introduction of non-natives should the climate become unsuitable in their native range (Thomas 2011). Even without translocation, climate change presents challenges to our perception of species' 'natural ranges' and what is a 'native' or 'non-native'; in some cases, species currently present as a result of human action might later colonise as a result of natural dispersal.

4.29 How many species will go extinct due to climate change and why? Recent global analyses, suggest that by 2050, 15% to 37% of terrestrial plants and animals worldwide could be 'committed to extinction' due to climate change (Thomas *et al.* 2004). Recent Natural England funded research has identified the risks and opportunities posed by climate change for over 3000 species of a wide range of taxa, and 27-35% are threatened by climate change. Other research funded by Natural England has identified areas across England that have features that correlate with past species persistence, and so might have the potential to act as refugia under future climate change (Suggitt *et al.* 2014) The full implications of such analyses and investigations have yet to be explored with respect to England's biodiversity.

5. The conservation and value of biodiversity

What we know:

5.1 We know our overall conservation objectives for biodiversity at international and England levels. The Biodiversity 2020 strategy (Defra 2011) includes a number of quantified outcomes to be achieved by 2020, which are themselves consistent with European and international commitments. These commitments, as well as related requirements such as those of the Water Framework Directive, are important in guiding the magnitude and types of conservation action by Natural England. Considerable amounts of conservation action are also carried out by other Government bodies such as Environment Agency and Forestry Commission, as well as Non-Governmental Organisations such as RSPB, The National Trust and the Wildlife Trusts, and often in partnership with Natural England.

5.2 Protected areas form a critical part of nature conservation approaches around the world, on land and at sea and there is increasing evidence that they deliver significant benefits to wildlife and people (Convention on Biological Diversity 2008; Ervin *et al.* 2010; Taylor *et al.* 2011; Gormley *et al.* 2012). They are central to the conservation of biodiversity in England, providing core areas of high quality habitat for our biodiversity, and are a key component of England's development of a coherent ecological network (Lawton *et al.* 2010). There is also evidence that they are important sites for species colonising new areas of England (Thomas *et al.* 2012).

5.3 England's core protected site network is its Sites of Special Scientific Interest. Nationally important SSSIs are designated with the aim of conserving specific biological or geological features. In total, there are just over 4100 SSSIs, covering about 8% of England, and about 70% of this area is also designated as Special Conservation Areas (SACs), Special Protection Areas (SPAs) or Ramsar sites. The proportion of the UK's terrestrial area covered by SACs and SPAs is the lowest in Europe (the European average is 17.5% compared with 4.9% for England; European Commission 2010 and Natural England data). Some of the very best wildlife sites are nature reserves held by NGO conservation organisations, or have been designated National Nature Reserves (there are 224 NNRs in England, covering 94,400 ha). There are also local biodiversity designations, including over 1400 Local Nature Reserves and more than 42,000 Local Wildlife Sites (Lawton *et al.* 2010).

5.4 We know the current and likely future condition of notified features on SSSIs and have identified threats to future condition. The condition of SSSI designated features is assessed on a rolling programme against agreed standards. Currently 38% of SSSI area is in favourable condition and a further 59% in 'unfavourable recovering' condition (Defra 2014). (Note the category of 'unfavourable recovering' usually means that appropriate management is believed to be in place rather than there being definite evidence of improvement derived from environmental monitoring).

5.5 On land, England's SSSIs contain > 60% of the remaining priority habitat for three quarters of our priority habitat types (Lawton *et al.* 2010). The main exceptions are woodlands, coastal floodplain grazing marsh, neutral grasslands, arable field margins and species-rich hedgerows, much of which occurs outside any designation.

5.6 The protection of England's priority marine habitats has increased markedly since 2011 (Defra 2014). Approximately 1.1 million ha of English seas have been designated as Marine Protected Areas (SACs and SPAs). This represents 21% of England's inshore waters, and is a greater area than covered by terrestrial protected sites. The Government is committed to establishing a coherent network of Marine Conservation Zones that will protect habitats and species while also taking social and economic factors into account – some 127 MCZs have been recommended for designation, covering 15% of the Defra marine area (ie English territorial waters and UK offshore waters adjacent to England, Wales and Northern Ireland); 27 have currently been designated.

5.7 SSSIs do not contain representatives of all threatened or priority species. There are known SSSI gaps for certain types of species, such as grassland fungi for which SSSI selection guidelines were only published in 2009 (Genney *et al.* 2009). A number of notably rare species lie outside the SSSI series, eg the endemic lichen *Lecidea subspeira* which is known globally only from a single churchyard in West Sussex. At UK level, 12% of 371 threatened vascular plant species are not represented within the SSSI series (Jackson *et al.* 2009).

5.8 Conservation management of SSSIs (and Natura 2000 sites) is targeted at the species and habitats that are listed as features of interest. Thus, there may be priority habitats and species that are not subject to appropriate management on protected sites.

5.9 England's wildlife sites cannot yet be regarded as comprising a coherent and resilient ecological network capable of coping with current and future pressures. Many of England's wildlife sites are small – over 77% of SSSIs and 98% of Local Wildlife Sites are smaller than 100 ha - and these sites are often surrounded by land that is increasingly hostile to species movement (Lawton *et al.* 2010).

5.10 Site heterogeneity (ie physical variability) and size are both important determinants of how many species a site can support. Large areas usually contain more species than smaller areas (the 'species-area relationship'; Connor & McCoy 1979). This is because larger populations are less prone to local extinction (in a hard winter, for example) and because larger sites are likely to be more physically variable (in their geology, topology, and variety of habitats), providing greater niche diversity which enables more species to coexist (Rosenzweig 1995; Whittaker & Fernández-Palacios 2007; Báldi 2008).

5.11 In general, we know how to manage our priority habitats to maintain and enhance their conservation interest, and we know that certain agri-environment schemes can be successful in habitat restoration and creation. Recent work has shown that Environmental Stewardship can improve

the population growth rates of granivorous birds (Baker *et al.* 2012), arable field margins can be beneficial to bumblebees (Carvell *et al.* 2007), and measures targeted at one species can be beneficial for other biodiversity elements as shown for stone curlew (MacDonald *et al.* 2012b) and cirl bunting (MacDonald *et al.* 2012a) although such interventions may not be sufficient in all cases (eg for lapwing in the uplands (Smart *et al.* 2013)).

5.12 We have determined what we believe to be the likely niche requirements of most priority species, based mainly on information known by experts about similar species (Webb *et al.* 2010; Dolman *et al.* 2011). However, we also know that there is currently **no significant correlation between the trends of priority habitats and their associated species,** indicating that habitat management has not always delivered what the species need (Brotherton & Webb 2010). In the absence of precise information on these species' requirements, management based on the niche requirements of similar species is considered the best way forward.

5.13 Conservation interventions can be successful in halting and reversing species declines, particularly for those with restricted ranges (eg UK Biodiversity Group 2001). We have, for example, re-instated lost populations of species (eg dormouse and wart-biter cricket), and recovery can lead to the removal of species from the UK BAP priority list (eg prickly sedge and Adonis blue butterfly) (BRIG 2007). We have successfully reintroduced red kite and large blue butterfly that had been lost altogether from England and reintroductions are underway for pool frog, corncrake, great bustard, interrupted brome and short-haired bumblebee (Natural England 2010). The levers that we have at our disposal, in particular species-specific site management, make it easier to reverse the declines of localised species. Wider environment programmes can also prove successful (eg for otter, cirl bunting in Devon, and stone curlew: Burns *et al.* 2013; MacDonald *et al.* 2012a & b).

5.14 We broadly know how to manage species, sites and landscapes, in ways that enhance biodiversity today and enhance the capacity to adapt to climate change in the future (Hopkins *et al.* 2007; Smithers *et al.* 2008). The Climate Change Adaptation Manual provides more detailed management prescriptions for land managers (Natural England & RSPB 2014).

5.15 Biodiversity is important for our economy and well-being, and 30% of UK ecosystem services are in decline (UK National Ecosystem Assessment 2011). The annual value of UK fish landings is about £600 million; biodiversity pollination services are worth an estimated £430 million in the UK; and the water quality benefits of inland wetlands may be as high as £1,500 million per year (UK National Ecosystem Assessment 2011). There are also strong positive correlations between human physical & mental health and biodiversity (Maller *et al.* 2005; Stone 2009). Many of the valuable supporting ecosystem processes supported by biodiversity, and threatened by its loss, are carried out by small, numerous organisms, whose conservation status is least known.

5.16 Our main conservation activities deliver significant benefits to people. The wildlife, landscape and carbon benefits of our agri-environment schemes to society outweigh the costs by approximately 3:1 (Boatman *et al.* 2010). The benefit:cost ratio for our biodiversity action plan targets is at least 2:1 (Christie *et al.* 2011). The annual benefits of maintaining SSSIs in their current status is estimated at £956 million per year versus an estimated cost of approximately £110 million per year (GHK 2011).

What we do not know:

5.17 We do not have adequate information on the status and ecological requirements of threatened (and other) species on each designated site and how they make use of, and are dependent upon, adjacent undesignated land. At times this lack of knowledge can lead to damaging management for some species (eg poor management may have contributed to the extinction of the starry breck-lichen, which was lost from its last Breckland site at the start of the 21st century; Defra 2006).

5.18 There are significant gaps in our knowledge about the extent, value and condition of Local Wildlife Sites (LWS). We lack knowledge of LWS boundaries in certain areas; most do not have conservation objectives and the majority (about 53%) are not under appropriate management (Defra 2014). Most LWS are privately owned, but their owners may be unaware of their status because there is no requirement to notify owners when LWS are identified.

5.19 In most cases, we do not know what population size or range is sufficient for species to be considered self-sustaining. Although the Habitats Directive requires us to achieve 'favourable conservation status' of many species, the reference values relate to population parameters at the time the Directive came into force (1992), not an objective understanding of what is required for the species to be secure. Many species are dispersed amongst a network of patches that interchange individuals through immigration and emigration, forming metapopulations (Levins 1969; Hanski 1994; Moilanen *et al.* 2005). The use of metapopulation dynamics to guide conservation planning and management is undeveloped in England, but could play an important role (eg Hodgson *et al.* 2009).

5.20 We do not have a good knowledge of the dispersal abilities of many species, so we cannot be confident that they will be able to occupy newly created habitat without targeted intervention. Further, we have insufficient understanding to be able to determine the relative importance of different spatial habitat elements (eg patch size and shape, patch quality, inter-patch distance, the role of the intervening matrix) for different species and to design conservation landscapes accordingly.

5.21 We do not know the economic value of biodiversity, ecosystems and ecosystem services across the full range of circumstances in which they occur. We have some evidence on economic values but this is derived from a limited number of primary valuation studies that are not transferable. Economic valuation techniques are limited and cannot be applied easily to inform conservation decisions. We also do not understand the links between biodiversity and economic activity, which is due to temporal effects as well as the complexity of these linkages.

5.22 We do not know what might be the consequence for conservation of major changes in the uptake or funding of agri-environment schemes. Current incentives and compensation to farmers and other landowners to undertake environmental land management is based on relatively short-term (5 -10 year) agreements, and biodiversity gains might be lost should such land not be re-entered into agreements: renewals of agreements are an essential part of maintaining progress to the outcomes of Biodiversity 2020.

Areas of active research or debate:

5.23 We have limited information on how long it will take priority habitats to recover, and consequently for SSSIs to reach favourable condition. This is likely to vary according to the 'starting' condition, the habitat type, and the management approach, making it difficult to be confident that we will

meet policy commitments. Current research projects are reviewing the published and unpublished literature to provide a better evidence base and to identify areas that need further research.

5.24 How to design coherent and resilient ecological networks. Lawton *et al.* (2010) provided a prioritised set of ecological solutions to support the establishment of ecological networks. Natural England is undertaking research to investigate how these principles can be applied in real-world situations. There are issues to be explored about the relative importance of corridors for various taxa and the degree to which enhanced connectivity for one group of organisms might provide increased barriers to others – especially where habitat structure (eg woodland vs. grassland habitats) is important.

5.25 How conservation spatial targeting and systematic planning tools can be applied to the English situation. There is now a number of practical tools, such as 'Marxan' and 'Zonation', that can help optimise the cost effectiveness of site selection in the development of ecological networks. Systematic conservation planning approaches have the potential to aid the targeting of much of our conservation work (Margules & Pressey 2000; Delavenne *et al.* 2012) and Natural England has begun to explore these techniques.

5.26 The extent to which we need new approaches to designation and management in the face of ongoing environmental change. Nature conservation priorities for sites have largely been about maintaining communities, assemblages and species present at the time of designation. Natural England's designations strategy suggests a more dynamic approach is required and recent work shows how species populations can be maintained within a protected areas network as a whole, even though there may be considerable turnover and changes on individual sites within the network (Johnston *et al.* 2013).

5.27 The extent to which we can manage designated sites and priority habitats so that they support larger populations of a greater diversity of species. The analysis of the niche requirements of many species (Webb *et al.* 2010; Dolman *et al.* 2011) suggests that it should be possible to manage habitats in ways that provide a greater diversity ('heterogeneity') of high quality niches (now known as the 'mosaic approach'). Natural England has developed information notes and is assessing how the approach can be translated into management guidelines or prescriptions to deliver these 'new' habitats.

5.28 How long it takes to restore or create habitats, and what management methods are suitable to achieve this. Research to improve our understanding of appropriate methodologies is underway for a number of habitats including grasslands (Defra research project BD1459) and blanket bog (Defra research project BD5401). The Biodiversity Action Reporting System (BARS) provides a source of data on what and where conservation interventions are being undertaken. This can be used in the future to identify timescales and success rates of different types of action to restore and create habitats under a wide range of different local conditions.

5.29 Whether we can apply the 'farmland bird' model to other species groups. Many years of research has enabled Natural England to design 'farmland bird packages' which are easy to understand and which deliver the types and amount of habitat that farmland bird populations need in order to recover. In partnership with Butterfly Conservation, Natural England has developed a Farmland Butterfly Initiative and, in response to recent concern over the fate of wild pollinators in the countryside, proposals have been made for a package that would provide for nectar food, larval food and hibernation sites.

5.30 How multi-objective approaches compare with more targeted, focussed action. Multiple objective delivery mechanisms attempt to secure biodiversity gains alongside interventions taken for other interests (eg resource protection or tourism). However, most of the examples of successful conservation delivery currently come from highly targeted interventions for species or habitats. There is debate over where multi-objective approaches are best able to deliver measurable increases in biodiversity.

5.31 The role of re-wilding in management of landscapes. A more 'open-ended approach' to ecosystem restoration, in which human intervention is minimal is a potential conservation option (Hughes *et al.* 2011; Navarro & Pereira 2012). Monitoring of projects with re-wilding aspects in England (eg at Ennerdale, the Great Fen, Wicken Fen and Knepp Estate) provide opportunities to understand the potential contribution of re-wilding approaches in achieving our environmental objectives (Hughes *et al.* 2011).

5.32 What appropriate balance of 'land sharing' and 'land sparing' will deliver the most for biodiversity while still meeting other societal needs? Research being undertaken by Natural England and others aims to evaluate the relative benefits of integrating biodiversity conservation alongside food production (requiring less intensive farming) ('land sharing') as opposed to protecting more land specifically for biodiversity and accepting greater intensification elsewhere ('land sparing') (eg Phalan *et al.* 2011).

5.33 Whether biodiversity offsetting can be effective as a conservation mechanism in an English context. Can biodiversity offsetting (conservation activities designed to deliver biodiversity benefits in compensation for losses, in a measurable way) work in ways that improve our ability to achieve no net loss for biodiversity, or net gain, or will it become a 'license to trash'? Eight pilots were instigated to test this approach, with Natural England playing a key support role (see: **www.defra.gov.uk/environment/natural/biodiversity/uk/offsetting**).

6. Current Natural England evidence projects

6.1 Priority habitat inventories. This includes several separate evidence projects to update the quality of habitat inventory information, and ultimately produce a single GIS-layer containing all priority habitats (NE evidence projects include RP0326 and RP0475[1]).

6.2 Habitat condition surveys. Natural England is managing a series of contracts to improve our understanding of (and assessment methodologies for) the condition of priority habitats (eg upland habitat condition surveys, RP0043).

6.3 Integrated Site Assessment programme. This programme is developing an integrated approach to Natural England's in-house site monitoring, including for SSSIs and HLS agreements (RP0315).

6.4 SSSI notification strategy. This strategy aims to ensure that the SSSI series remains fit for purpose. It provides for the series to be reviewed and new sites to be selected (and, in exceptional

[1] RP numbers refer to projects held in Natural England's Evidence Projects Database.

circumstances, sites to be de-notified). Details are at: **www.gov.uk/government/publications/sites-of-special-scientific-interest-designation/sites-of-special-scientific-interest-designation**.

6.5 Species Recovery Programme. Natural England reviews the conservation requirements of priority species, prioritises the urgency for action, funds research into understanding the ecology, causes of decline, methods for action and trials conservation action through this programme.

6.6 The Biodiversity Action Reporting System (BARS) is a web-based information system that records where practical action is in place to benefit important habitats and species. It establishes the level of activity in place at any given time, where this is taking place, and what it is trying to achieve. BARS can be used to map action locations and generate a range of statistical summaries. (**www.ukbars.defra.gov.uk/**).

6.7 Ecological networks research programme. This cross-cutting programme of research projects aims to develop design principles for ecological networks that integrate environmental objectives, including maximising networks' climate change adaptation potential. Projects include: a review of large-scale conservation in Britain (RP0522); the potential for climate change refugia in England (Suggitt *et al.* 2014); evaluating the risks of invasive species spreading within networks (Knight *et al.* 2014); the role of landscape and site characteristics in network site resilience (Oliver *et al.* 2013; Newson *et al.* 2014); the socio-cultural dimension in landscape-scale network planning (RP0934); exploring the use of spatial models for planning networks (RP1870); exploring how network attributes (eg patch size, age, shape etc) affect woodland biodiversity (RP1410). The results are contributing to NERC-funded Knowledge Exchange projects with the Universities of Liverpool and Exeter to develop practical advice and guidance.

6.8 Long term monitoring network – a programme of monitoring on 40 NNRs in England, covering weather, soils, soil biodiversity, birds and butterflies (RP0316). The aim is to monitor impacts of climate change, pollution and land management. It is part of the UK Environmental Change Network (see 7.12).

6.9 Natural England Evidence Reviews (RP0834) – These are systematic reviews of contentious environmental topics, and so far have focussed on key upland issues, including blanket bog restoration, hay meadow management, grazing, and the impacts of tracks and rotational burning on blanket bog. **Natural England Evidence Reviews**.

6.10 Improvement Programe for England's Natura 2000 Sites (IPENS) – is a partnership project between Natural England and the Environment Agency, supported by EU LIFE+ funding. The project analyses the risks and threats to each Natura 2000 site, assesses actions and mechanisms which may counter them. Theme plans address national issues that affect individual sites eg nitrogen deposition, coastal squeeze and impacts of non-native species.
www.gov.uk/government/publications/improvement-programme-for-englands-natura-2000-sites-ipens.

6.11 Evidence Project Database. A list of current biodiversity (and other) research and monitoring projects is available on Natural England's internal systems. We are currently working on making this available to everyone. In the meantime a list of Natural England's evidence projects that were current in 2014 can be seen on the National Archives at:
http://webarchive.nationalarchives.gov.uk/20140711133551/http://www.naturalengland.org.uk/ourwork/evidence/register/default.aspx

7. Key external research programmes

7.1 Defra's biodiversity evidence programme covers diverse policy areas including internationally and nationally designated protected sites, conservation of priority species and habitats, mitigating the effects of climate change on biodiversity, ensuring biodiversity is able to adapt to climate change, and wildlife management and protection. Link: **www.gov.uk/government/uploads/system/uploads/attachment_data/file/221078/pb13908-evidenceplan-biodiversity-ecosystems.pdf**.

7.2 Defra's Sustainable Land & Soils and Sustainable & Competitive Farming Strategy Joint Evidence Programme cover agri-environment scheme option development, integrated farming systems, landscape-scale processes including the development of ecological networks, monitoring and evaluation of environmental land management schemes, and the development of a Sustainable Intensification research Platform. Link: **www.gov.uk/government/uploads/system/uploads/attachment_data/file/221058/pb13928-evidenceplan-land-soils-farming-strategy.pdf**.

7.3 Forestry Commission research programmes in particular those dealing with woodland biodiversity. Link: **www.forestresearch.gov.uk/fr/infd-5stc6j**.

7.4 The Countryside Survey provides an important audit of the natural resources of the UK's countryside. The Survey has been carried out at regular intervals since 1978. The countryside is sampled and studied using rigorous scientific methods, allowing us to detect the gradual and subtle changes that occur in the UK's countryside over time. Link: **www.countrysidesurvey.org.uk**.

7.5 Species monitoring programmes provide important long-term sources of information on trends of different species groups, increasingly at sufficient resolution to answer important research questions. Most of these datasets are available via the National Biodiversity Network (**www.nbn.org.uk/**), and recording schemes are coordinated through the Biological Record Centre (**www.brc.ac.uk**), hosted by Centre for Ecology and Hydrology (CEH). Examples of key schemes include the breeding bird survey (**www.bto.org/volunteer-surveys/bbs**); butterfly and moth recording (**www.butterfly-conservation.org/text/36/recording_monitoring.html**); and the national bat monitoring programme (**www.bats.org.uk/pages/nbmp.html**).

7.6 Invasive species: A number of programmes are now undertaking the recording of non-native species, coordinated by the Non-Native Species Secretariat. This includes the Recording Invasive Species Counts (RISC) project that closely monitors 21 invasive non-native species. Link: **www.nonnativespecies.org//index.cfm?sectionid=81**.

7.7 Conservation Evidence is a programme led by William Sutherland at Cambridge University. It aims to provide a free, authoritative information resource designed to support decisions about how to maintain and restore global biodiversity. The programme summarises evidence from the scientific literature about the effects of conservation interventions such as methods of habitat or species management. Link: **www.conservationevidence.com**.

7.8 The Collaboration for Environmental Evidence synthesises evidence on issues of greatest concern to environmental policy and practice. Syntheses are systematic reviews providing rigorous and

transparent methodology to assess the impacts of human activity and effectiveness of policy and management interventions. Link: **www.environmentalevidence.org/**.

7.9 The UK National Ecosystem Assessment (UK NEA) analysed the benefits the natural environment provides to society and continuing economic prosperity. The first phase reported in early 2011 and a second phase is now underway to further develop the arguments and make them applicable to decision and policy making at a range of spatial scales across the UK and to a wide range of stakeholders. Link: **http://uknea.unep-wcmc.org/**.

7.10 The Valuing Nature Network supports interdisciplinary partnerships to research the valuation of biodiversity, ecosystem services and natural resources and facilitate the integration of such approaches in policy and practice in the public and private sectors. Ten research projects are currently underway. Link: **www.valuing-nature.net**.

7.11 The Economics of Ecosystems and Biodiversity (TEEB) study is a major international initiative to draw attention to the global economic benefits of biodiversity, to highlight the growing costs of biodiversity loss and ecosystem degradation, and to draw together expertise from the fields of science, economics and policy to enable practical actions moving forward. Link**: www.teebweb.org/**.

7.12 Biodiversity Impacts of Climate Change Observation Network (BICCO-Net). A joint research initiative funded by Defra, Countryside Council for Wales (Now Natural Resources Wales), National Institute for Agricultural Engineering (NIAE), Natural England and Scottish Natural Heritage and managed by Joint Nature Conservation Committee. Partners include BTO, Bat Conservation Trust, and Rothamsted Research. The initiative aims to collate and analyse relationships between terrestrial and freshwater species populations and climate across different monitoring schemes and taxa. Link**: www.bicco-net.org**.

7.13 UK Environmental Change Network (ECN). A long-term monitoring programme measuring a wide range of biological and physical variables (including detailed climate recording) at intensively studied sites. This is part of the International Long Term Ecological Research (ILTER) Network. Link: **www.ecn.ac.uk**.

7.14 The Biodiversity and Ecosystem Service Sustainability Programme (BESS) is a six-year (2011-2017) Natural Environment Research Council (NERC) research programme, designed to answer fundamental questions about the functional role of biodiversity in key ecosystem processes; the flows of ecosystem services across landscapes; and how these are likely to change in an uncertain future. The secretariat is at the University of East Anglia, led by Ian Bateman. Link: **www.nerc-bess.net/**.

7.15 The JNCC-BTO Partnership for Monitoring Birds and the Environment. This is the latest in a series of long-term partnership agreements between JNCC (on behalf of country agencies, including Natural England) that aims to monitor bird populations, using mainly volunteer effort, and to investigate the causes of bird population declines. Information from the monitoring schemes is provided through the BTO website (**www.bto.org**) and notably on the BirdTrends site **www.bto.org/birdtrends**.

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