Natural England Research Report NERR071

Generating more integrated biodiversity objectives – rationale, principles and practice

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Chris Mainstone, Richard Jefferson, Iain Diack, Isabel Alonso, Alistair Crowle, Sue Rees, Emma Goldberg, Jon Webb, Allan Drewitt, Ian Taylor, Jonathan Cox, Paul Edger, Katherine Walsh

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Project manager

Chris Mainstone
Natural England
Suite D
Unex House
Bourges Boulevard
Peterborough
PE1 1NG
chris.mainstone@naturalengland.org.uk

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Executive Summary

Effective biodiversity conservation can be hampered by the compartmentalisation of technical advice, guidance, objectives and strategy according to habitat types, species groups and individual species. Whilst specialists on individual components of biodiversity, as well as local biodiversity decision-makers, often possess a holistic mindset to wildlife conservation, it is not necessarily easy to apply that mindset within such a compartmentalised framework. A more technically integrated approach to biodiversity decision-making would help to deliver greater benefits for our habitats and species in the round, whilst creating sustainable management opportunities that enhance natural capital and generate greater resilience in our ecosystems.

This report covers all terrestrial and freshwater-related habitats and their species complements but does not extend to the marine environment. Many of the issues encountered in marine habitats mirror those found in terrestrial and freshwater-related habitats, and as a result much of the rationale and many of the outlined in this report are also applicable (and already applied) in a marine context.

The intention of the report is that it will provide a more harmonised technical basis for specialist advice within Natural England, and help partners and stakeholders to understand our rationale for more integrated biodiversity decision-making. It should be seen as critical ecosystem detail for applying the 'ecosystem approach' (adopted under the International Convention on Biological Diversity), which provides a wider framework for environmental decision-making.

The project has focused on understanding how different habitat types function and relate to each other naturally in the landscape to provide the combination of structure and niches required to support and safeguard our native wildlife. This has involved consideration of: habitat mosaics at a range of spatial scales, the extent to which current approaches to the conservation of habitat types satisfies the needs of individual species and *vice versa*, and the role of different elements of natural function (hydrological, nutrient status, soil and sediment processes, natural influences on vegetation succession, and the naturalness of biological assemblages). As part of these considerations the scope and desirability of restoring different elements of natural function in different habitat types was evaluated.

Discussions within this project highlighted the key influence of cultural management regimes and associated management boundaries on the existing pattern of biodiversity in England, and the effects of this on the way we perceive habitats and species assemblages in biodiversity conservation. The application of habitat and assemblage classifications in management decision-making can reinforce this cultural perspective and constrain perceptions of how habitats function naturally – their dynamic nature in space and time, natural transitions, and the multiple spatial scales at which habitats exist in mosaics and provide for species.

A dichotomy is evident between management philosophies based on: 1) accepting cultural landscapes as the reference point for biodiversity conservation, enhancing them to help certain species and species assemblages; and 2) using natural processes as a reference point, seeking restoration of naturally functioning habitat mosaics within which all characteristic wildlife can thrive. Extreme portrayals of these philosophies (species gardening on the one hand, and rewilding on the other) obscure the importance of both in biodiversity conservation and the need for an appropriate balance between the two in local decision-making and spatial planning.

An integrated approach to biodiversity conservation requires a combination of sound ecological rationale and pragmatism – the latter relates to being realistic about what is possible where and taking the best opportunities that present themselves. This is partly about striking the right balance between the concepts of 'land-sparing' for biodiversity and 'land-sharing' (in which some biodiversity objectives are delivered along with other socioeconomic objectives), and being clear about what these terms mean in practice.

Encouraging a suitable approach to the local technical evaluation of management and restoration options is the most important step, rather than trying to prescribe specific local outcomes. What is possible at any one location depends on local constraints and opportunities - an informed approach to evaluation and decision-making helps to identify and then seize the opportunities for more integrated biodiversity outcomes that are available.

A set of principles has been developed to help with evaluation and decision-making, with the overall aim ***'to promote the protection and restoration of natural ecosystem function where this is possible and desirable'.*** This general aim was felt to strike an appropriate balance between the need for a sound ecological foundation for integration on the one hand and maintaining realism about what can be achieved in our cultural landscapes on the other. It allows encouragement of a greater focus on the naturally functioning habitat mosaics within which our native species evolved, without trying to force impractical outcomes in any particular situation. It also provides critical alignment with efforts to enhance natural capital, for instance through restoring the ability of landscapes to moderate flooding and store water and carbon,

Some of these principles are ecological in nature, emphasising the importance of considering how different habitats and their species naturally sit in landscapes and using this as a template for biodiversity planning. Others relate to handling local operational realities, recognising permanent constraints to restoring more naturally functioning habitat mosaics (but encouraging a long-term perspective so that short-term constraints do not unduly influence decision-making), and identifying and promoting synergies with other environmental objectives. These principles can be applied at a range of spatial scales, but there are trade-offs: increasing scale provides greater flexibility for satisfying biodiversity needs in a holistic way and greater likelihood of practical opportunities, but can increase the complexity of evaluation and planning and introduce greater numbers of practical constraints. The application of these principles to different landscapes and in real situations is illustrated using a range of case studies.

A great deal can be done at relatively small spatial scales as long as practical opportunities exist – finding such locations is an important task and often requires evaluation of larger areas, of both semi-natural and developed land. A key pitfall to avoid is that, in taking opportunities to enhance particular species within developed land (such as intensively managed agricultural fields), we do not constrain (or deflect attention from) opportunities for restoring naturally functioning habitat mosaics which would provide for characteristic assemblages more widely and still deliver for target species.

In many ways these principles simply help codify the type of decision-making already applied by experienced local Natural England staff and stakeholders. Consistent application of the principles within the advice given by habitat and species specialists should support and promote their wider adoption at a local level. Improving transparency in evaluation and decision-making, backed up by evidence about ecological relationships between species and habitat features and the benefits of using natural function as a means of achieving objectives, will help foster support for such decision-making.

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1 Introduction

Advisory, evaluation and strategic decision-making processes for conserving biodiversity tend to be divided into manageable compartments: habitat types, species assemblages and individual species. This can work against the integration of conservation rationale and lead to undervaluing biodiversity elements that exist on the boundaries between those compartments. Unnecessary tensions can arise between objectives for different elements of biodiversity, and opportunities for integrated solutions that deliver greater biodiversity benefits can be missed. This can also lead to a failure to provide joined-up biodiversity messages to wider environmental evaluation and decision-making processes involving ecosystem services more generally (such as geodiversity, cultural and landscape objectives, flood regulation, water supply and water quality management and climate change adaptation), which can mean missing the most beneficial outcomes for wildlife and society. Approaches are needed to help break down the boundaries between the compartments that have been adopted to conserve biodiversity (Defra 2011).

A project was established within Natural England to bring national habitat and species specialists together to rationalise technical approaches to individual habitat types, species groups and priority species. A core working group of specialists was formed to provide representation of broad habitat types (woodland, open freshwaters, grassland, coastal, heathland, mires and upland habitats) and species groups (higher plants, lower plants, fungi, invertebrates, fish, birds, mammals and herpetofauna), The working group has been responsible for the production of this report, working with the wider cadre of habitat and species specialists in Natural England as well as a range of other national and local staff.

This report explores some ecological concepts of critical importance to more integrated decision-making, and provides a set of principles that can be applied at a local level to generate more harmonised biodiversity objectives that are fit for a changing climate. The main vehicles for integration that have been used in this project are **ecological relationships** and **natural function**, which are explained in Section 2 and expanded upon in subsequent sections.

The report stands as a technical rationale for integrating Natural England's specialist biodiversity advice, which partners and stakeholders can access to understand what we are seeking to achieve in our decision-making, as well as use to help inform their own management perspectives. It will hopefully underpin progressive discussions at a local level, in which Natural England can work with partners and stakeholders to build a shared vision for biodiversity within landscapes (Natural England 2016).

Whilst the scope of the work did not extend to the marine environment, the rationale and principles developed are highly relevant; indeed the approach taken by Natural England marine specialists is largely aligned with the rationale outlined in this report. A key difference relates to the consistent framing of marine principles at large scales (within a regional sea/marine ecosystem context), rather than the variable spatial scales implied on land. It is also important to note that, in common with freshwater and some other habitats, marine conservation strategy is strongly based on the protection and restoration of natural ecosystem function. This places it at the upper end of the naturalness spectrum of approaches to our habitats and species.

Natural England habitat and species specialists will endeavour to use these principles in providing their advice, including on:

- domestic Sites of Special Scientific Interest (SSSIs);
- the Natura series of Special Areas of Conservation (SACs) and Special Protection Areas (SPAs) and wider conservation of the habitats and species listed under the European 'Habitats' and 'Birds' Directives;

- wetland sites designated under the international ‘Ramsar’ convention; and ‘priority’ habitats and species under the UK’s commitments to the international convention on biological diversity (UK Biodiversity Steering Group 1995, CBD 1992) and listed for England under Section 41 of the CROW Act 2000).

Specialist advice is laid out in a range of habitat- and species-specific technical guidance documents on a wide range of issues, and the integration will need applied refinements of these documents as they come up for review. At an operational level, Natural England specialists will use the principles in this document to help local decision-makers identify the best resolutions to local conflicts between biodiversity and other objectives, helping to enhance England’s natural capital through an emphasis on natural ecosystem function.

Our native species are found in many different places, often exploiting highly developed environments (such as ditches and arable fields) that have certain characteristics in common with the natural habitats in which the species evolved (e.g. Hill *et al*. 2016). In some cases species have become strongly associated with highly developed environments and their natural niches have been largely forgotten. For instance, grass-wrack pondweed (*Potamogeton compressus)* is a species of lakes and sluggish rivers which is now strongly associated with ditches and canals, and the annual plants scarlet pimpernel (*Anagallis arvensis)* and ground pine (*Ajuga chamaepitys)* are plants of disturbed ground in open grassy vegetation (which naturally occurs in exposed cliff sites or woodland glades) but are now strongly associated with arable field margins. We need to exploit the opportunities and safeguard the havens that these highly modified environments provide. However, this report focuses on integrating our decision-making on semi-natural habitats, so that we can continue to strive to conserve our native species complement in the most naturally functioning ecosystems possible. Further explanation of this approach can be found in subsequent sections.

This report provides important technical underpinning for a wide range of cross-cutting initiatives within Natural England, under the umbrella of our corporate strategy ‘Conservation 21’ (Natural England 2016). It provides a key element of the technical rationale for the Ecological Networks Handbook (Natural England In Prep), which provides more detailed guidance on how to design ecologically resilient landscapes for multiple environmental and societal outcomes within the framework of the ‘ecosystem approach’. The report will become increasingly important as climate change means that habitats and species may thrive best in different places and different combinations than those where they occur now or did in the past (Natural England and RSPB, 2014), and will therefore help to deliver our commitments to climate change adaptation (Natural England 2015).

2 Explanation of key terms and concepts

2.1 Preamble

An integrated rationale for biodiversity decision-making requires a common understanding of key terms and concepts. The two key vehicles for improving integration in our biodiversity decision-making (ecological relationships and natural function) are dealt with in turn below. Many of the explanations of terms below come directly from the Convention of Biological Diversity (CBD, 1992), which forms a central pillar of European, UK and England biodiversity strategies. Finally, an explanation of the ecosystem approach and associated terms is also provided, to ensure that this report is viewed in the context of wider environmental decision-making.

2.2 Ecological relationships

The term ‘ecosystem’ means a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit" (CBD). There is no spatial or ecological scale attached to the term – they can be large or small areas, and involve high or low numbers of species.

The term ‘habitat’ means the place or type of site where an organism or population naturally occurs (CBD). It is therefore formally linked to individual species, rather than assemblages or communities.

The term ‘biodiversity’ (or ‘biological diversity’) means the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems. This implies that biodiversity is a product of ecosystems, and that importance is attached to the characteristic biodiversity of those ecosystems rather than simply species richness. Some ecosystems have characteristically hostile environmental conditions (e.g. severe hydraulic forces in rivers or exceptionally low nutrient availability) and low characteristic species richness as a result (Grime and Pierce 2012).

In practical conservation usage, the term ‘habitat’ is used more loosely to categorise environmental variation at a wide range of spatial and ecological scales, encompassing large and small-scale ecosystems and both natural and ‘developed’ environments. This usage is deeply embedded in legislation, operational processes and specialist advice, and cannot easily be changed. The term ‘ecosystem’ has largely entered into common usage through broader management concepts such as the ‘ecosystem approach’ and ‘ecosystem services’.

Habitat types, be they SSSI interest features, SAC features, priority habitats or types defined by the National Vegetation Classification (NVC, Rodwell 2006), also have no defined spatial scale. Each can cover a large or small spatial extent, but there is often a discernible hierarchy of ecological scale amongst them. For instance, a blanket bog is a large-scale peatland spreading across a landscape within which (as well as the large expanse of acid bog) are smaller component features, such as dystrophic pools (a SAC habitat feature in its own right) and small watercourses. In the same way, alkaline fen is a SAC habitat feature that develops around base-rich springs in a range of habitats including calcareous grasslands and woodlands. Individual species (again these may be SSSI, Natura or Ramsar features or biodiversity strategy ‘priority’ species) occupy habitat niches within these defined habitat features. An individual species may occupy a range of specific small-scale physical habitats through the course of its life cycle, and within any one life stage may oscillate between such habitats depending on season and daily meteorological conditions. Depending on the ecological scale of the habitat feature (how much environmental variation it supports) and the nature of the species, an individual species may be entirely or only partially catered for by the habitat feature (e.g. perhaps for only part of the species’ life cycle).

It is useful to organise our practical understanding of habitats, habitat mosaics and ecosystems into a framework that recognises this ecological and spatial hierarchy. An example schematic for river ecosystems is given in Figure 2.1. Organisms experience their environment at micro-habitat scale but typically require a pattern of micro-habitat provision at larger scales to fulfil their life-cycle requirements. Looking more widely, rivers sit within a broader habitat mosaic of wet and dry habitats within the landscape, and many species are dependent on that wider mosaic (Figure 2.2).

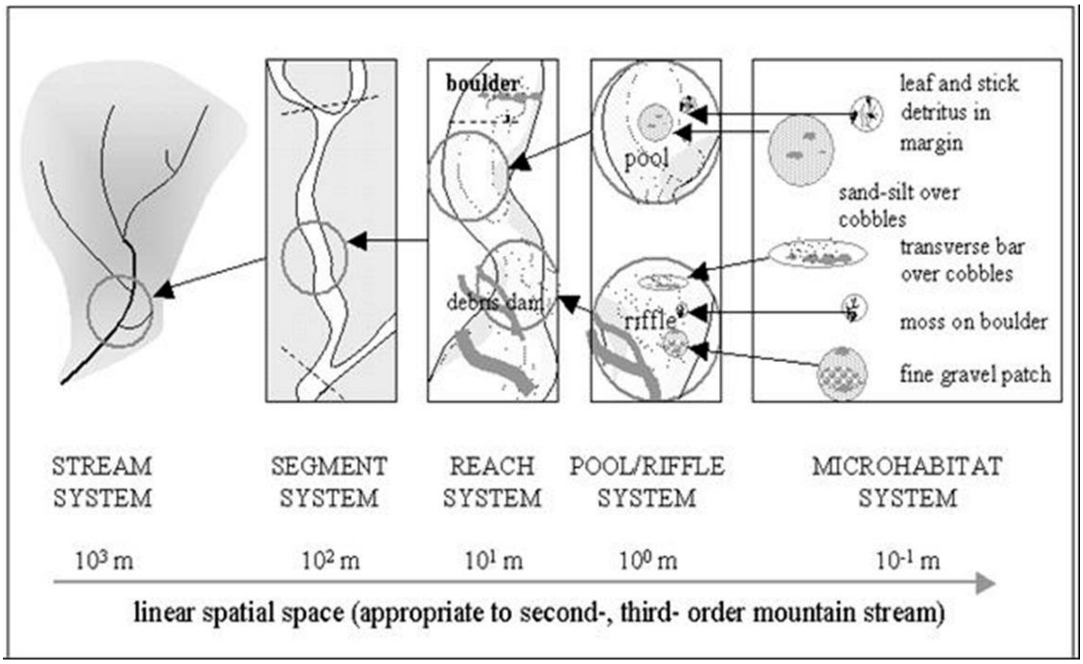


Figure 2.1 Example habitat hierarchy - river systems (after Frissell *et al*. 1986).

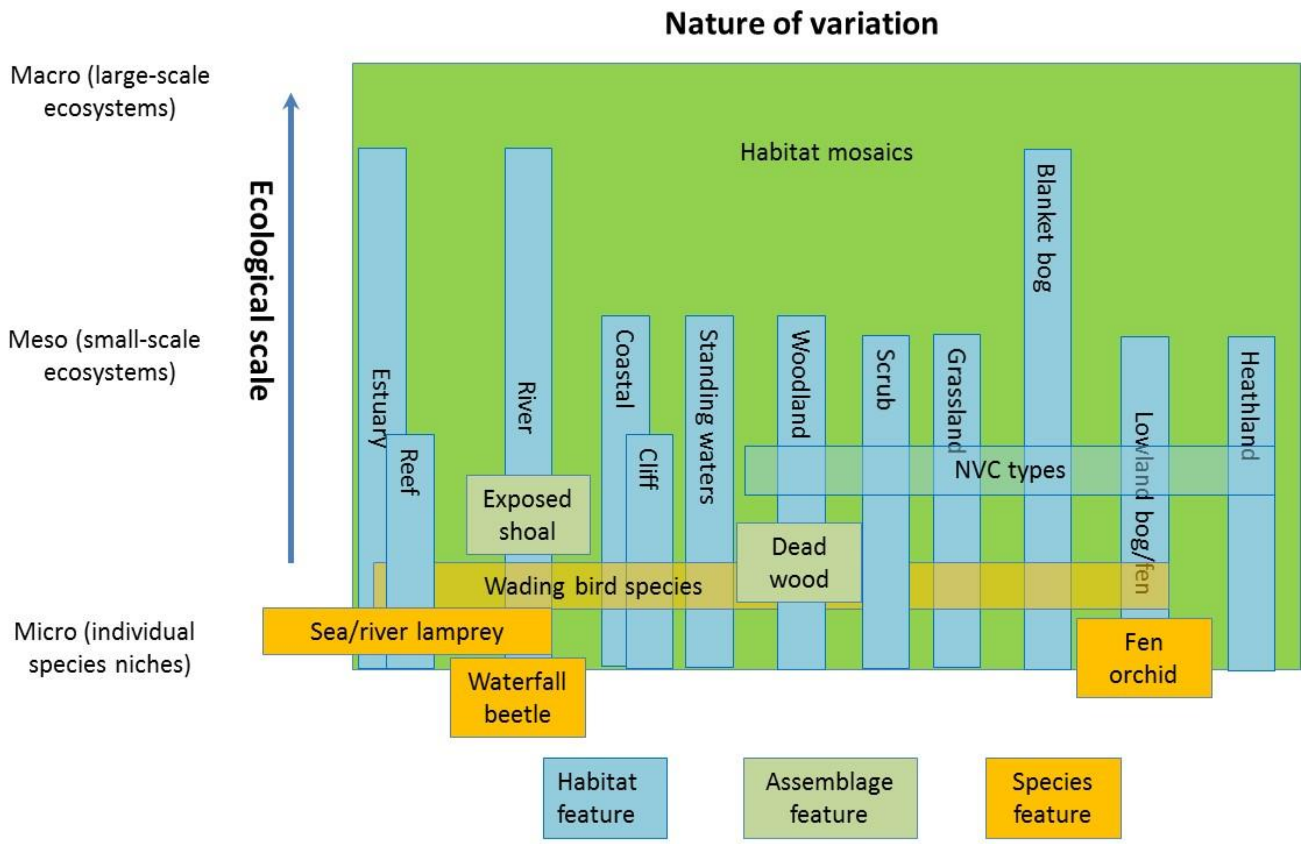


Figure 2.2 Wider ecological hierarchies and relationships (this is not intended to be exhaustive – in particular, only illustrative examples of smaller scale habitat features and assemblage/species features have been included).

Our structuring of decision-making in conservation management, based on defined habitat types and features, encourages a one-dimensional view of habitats which struggles with recognising these multiple scales of habitat and hence biodiversity variation and inter-dependency. In reality all of the defined habitat types we use in decision-making (SSSI and SAC features, priority habitats) are themselves habitat mosaics, which in turn nest in larger scale habitat mosaics.

At any given spatial scale we assign an area to a habitat type, and at that point there is a risk that natural smaller-scale variation in habitat is neglected. For instance, a woodland may be labelled as sessile oak woodland on dry acid soils, but within it there may be natural hydrological variations giving rise to small parcels of mire and flush habitat; unless our decision-making systems recognise this variation it may be eliminated by woodland management (e.g. drainage), or we may inadvertently fail to restore past damage to the natural habitat mosaic. On a different scale, the New Forest is internationally renowned as a unique surviving example of the ancient land management system of wood pasture, although much modified by modern forestry management. Within it there is a complex and internationally important mosaic of mire, wet and dry heath, flushes, runnels, streams and pools that are not evident from that portrayal, and which are fundamental to the site's biodiversity interest. This New Forest example is part of the same simplification process inherent in typologies, although with less risk to component habitats because of their scale and subsequent recognition as separate habitat features.

2.3 Natural function

This concept is expressed in different ways using subtle variations in terminology, but it essentially relates to the operation of ecosystems according to natural processes (abiotic and biotic). The precise definition of the term 'natural' has been a major topic of debate for decades, given that humans were a natural component of ecosystems before the major impacts of modern times.

Defining the point at which human interventions became damaging to natural ecosystems is a considerable challenge – perspectives vary between habitats, between species and between geographical locations. Some human interventions (e.g. development of floodplain meadow) have benefited some species (creating species-rich plant assemblages), whilst at the same time damaging (or destroying) more natural habitats (e.g. mires, wet woodland and streams). It is useful to think of a continuum of levels of natural function, within which there is a spectrum of impacts and a range of ecological and biodiversity consequences.

There are various abiotic and biotic natural processes that contribute to natural function. The topography, geology and climate of the landscape provides a natural template for hydrological and soil/sedimentary processes, over which a heterogeneous and patchy cloak of vegetation develops. Depending on the nature of natural processes, the vegetation will have varying degrees of stability across the landscape. Together the abiotic and vegetative components of the natural landscape provide dynamic habitat mosaics for characteristic assemblages (Figure 2.3). This can be regarded as the 'natural habitat template', which our native species have evolved to exploit.

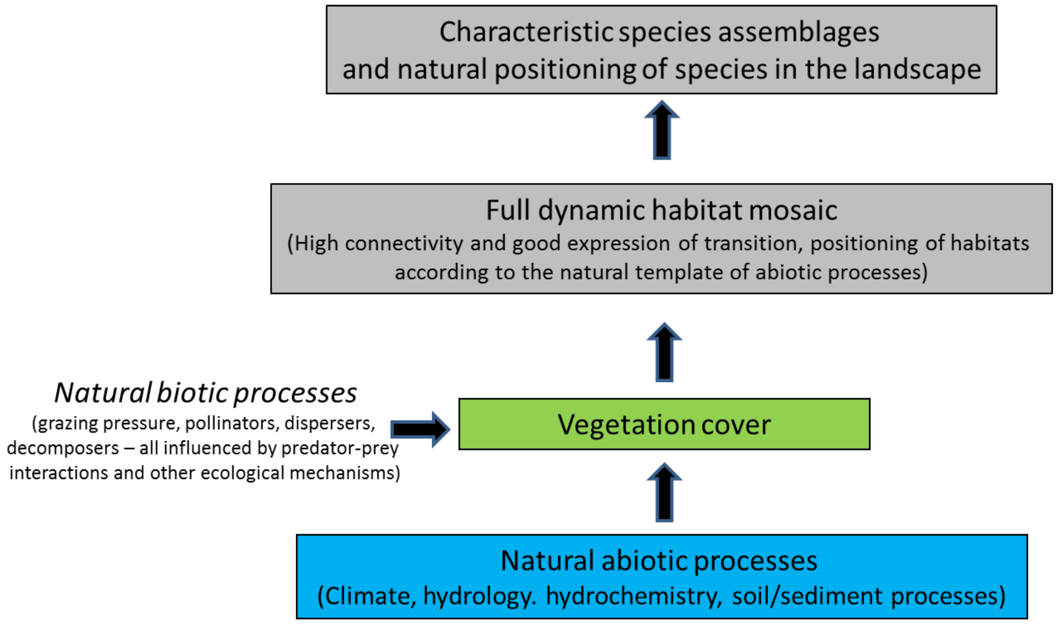


Figure 2.3. Naturally functioning landscape.

Processes of vegetation colonisation and succession (and hence habitat provision) are influenced by a combination of natural abiotic processes and natural biotic processes (grazing by wild herbivores, plant diseases etc.). All of our native species have their ecological positions in naturally functioning habitat mosaics, where their traits (physical and behavioural) evolved to fill specific habitat niches. The natural niches of species have become increasingly rare as the pace and duration of agricultural, forestry and urban development has increased (of course evolution is still occurring, and recent genetic selection in certain species to help exploit highly modified environments cannot be discounted).

Natural abiotic and biotic processes in some environments, such as river systems and coasts, are characterised by high levels of dynamism. Other environments, such as un-managed ancient woodland, can be relatively stable, although such systems are often punctuated by periodic dynamic events, often at small spatial scales (e.g. natural wind-throw of trees, soil disturbance and glade formation). High levels of natural dynamism are critical in some habitats to sustain the full expression of characteristic biological assemblages, particularly those species that have evolved to exploit disturbed conditions. For instance, in coastal systems marram grass traps sand and creates dunes, but becomes less vigorous when dunes become stable and more vigorous when sand-blow is reactivated. For other habitats certain species can only survive where conditions are naturally stable for sufficient periods of time, e.g. wood decay caused by fungi inside ancient trees for various invertebrate species, lack of soil disturbance for trees and long-lived perennial herbs). Even for species requiring stability, disturbance may be needed somewhere in the habitat mosaic to complete the life cycle – for instance, small-scale disturbance provides the bare ground conditions for seed germination and seedling development of long-lived perennial herbs.

Human interventions in the landscape can alter the underlying abiotic (e.g. natural hydrology is altered by land drainage and water management), soil or vegetation processes (e.g. through agricultural grazing and tillage or urban development), or all three (Figure 2.4). Some types and levels of human intervention (e.g. low intensity agricultural grazing) have allowed some native species to persist and often thrive by replacing natural large herbivore activity in the landscape, although at the same time have reduced habitat diversity/complexity leading to the loss of other aspects of biodiversity. This dual effect of so-called ‘cultural’ semi-natural habitats can create considerable tension in conservation decision-making, and it is this that lies at the heart of efforts to integrate biodiversity decision-making.

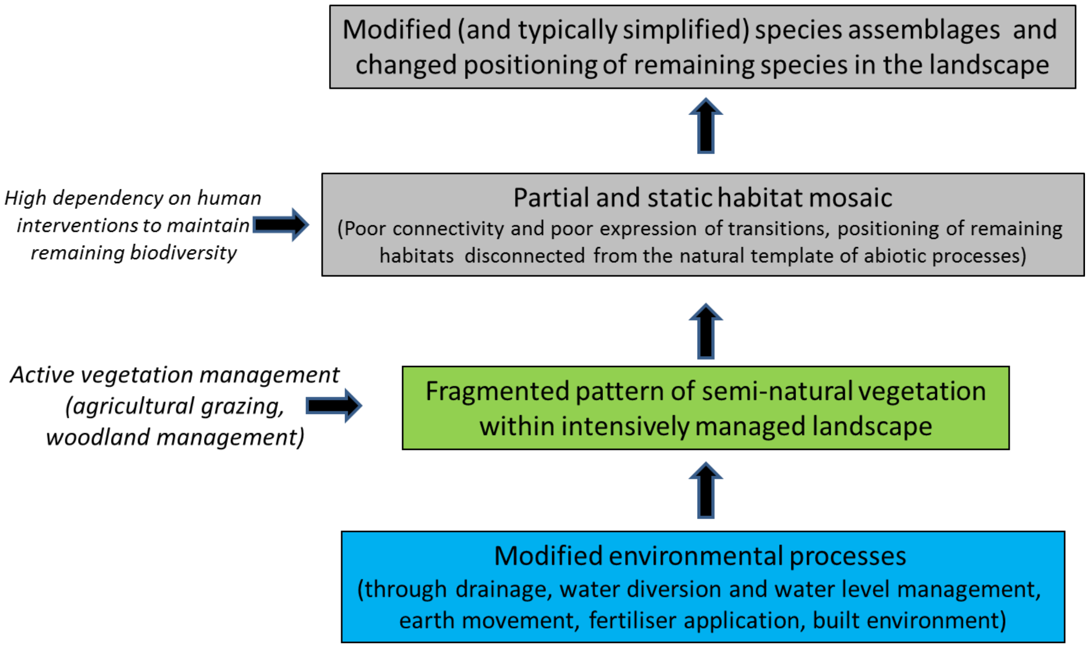


Figure 2.4 Functioning of modified landscape

Other more intense forms of human intervention (conventional modern arable and livestock farming, forestry, the built environment) have generated far greater impacts on natural ecosystems. Even in these heavily developed agricultural and built environments there is considerable scope for providing niches for native species, and this can be a major component of species conservation efforts. For example, concerted efforts are being made on intensively farmed land to reverse the decline in the populations of birds associated with relatively extensive farming systems, such as corn bunting and turtle dove.

Climate change is increasingly affecting biodiversity (Morecroft & Speakman, 2015) and its impacts will increase in future, not just as a result of rising temperatures, but also changing patterns of rainfall and extreme events such as droughts, floods and wildfire. It is also leading to rising sea level with consequent coastal erosion. Climate has always changed and natural ecosystems often have a capacity to naturally adjust, for example through changing stream courses and habitat mosaics together with species distribution changes. However the current rate of change is extremely fast compared to previous climatic changes and the lack of natural function reduces the capacity for autonomous adjustment. Restoring natural function generally increases resilience and facilitates climate change adaptation.

The terms **‘natural habitat function’ and ‘natural ecosystem function’** (which in common usage are largely synonymous) are used to emphasise the ecological nature of natural function and differentiate it from consideration of natural abiotic processes alone. This is important because attention to certain natural abiotic processes (such as hydrological pathways and natural soil and sediment behaviour) only *enables* natural habitat/ecosystem function. Whether that natural function is realised depends on a broader range of interactions between abiotic processes and biological assemblages.

2.4 The ecosystem approach and natural capital

The Convention on Biological Diversity adopted the ecosystem approach in 2000, as its primary framework for action. With its focus on both biodiversity and ecosystem services, the approach is defined by the Convention as "*a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way".* Amongst the 12 principles of the ecosystem approach, is Principle 5: *Conservation of* ***ecosystem structure and functioning,*** *in order to maintain ecosystem services, should be a priority target of the ecosystem approach.* This goes on to state that: *The conservation and, where appropriate, restoration of these interactions and processes is of* ***greater significance for the long-term maintenance of biological diversity*** *than simply protection of species.* This report can be seen as providing necessary technical detail and rationale for applying this principle.

Natural processes and functions are an integral part of 'natural capital', underpinning its ability to provide ecosystem services and benefits to people. The Natural Capital Committee (NCC) has defined natural capital as: "*the elements of nature that directly or indirectly produce value to people, including ecosystems, species, freshwater, land, minerals, the air and oceans,* ***as well as natural processes and functions***". The more intense forms of human intervention have often modified our ecosystems, landscapes and environmental processes to manage for just one ecosystem service, such as food from intensive agriculture. Naturally functioning landscapes, however, are able to support multiple ecosystem services (such as helping to regulate water quality, air quality, flooding and climate) as well as biodiversity.

3 Developing a more integrated framework for defining biodiversity objectives

3.1 Preamble

A more integrated perspective on ecological relationships and natural function could help greatly in developing local strategies for meeting multiple biodiversity objectives. Whilst greater consideration of ecological relationships (between habitats, between habitats and species, and between species) could achieve better integration on its own, linked consideration of natural function is required to fully address the challenges of planning more integrated biodiversity outcomes. This is because many of our habitats and species (including many of the most threatened) are heavily dependent on natural processes, and some of these processes (for instance hydrology) operate across landscapes. This in turn influences how we need to consider constraints and opportunities for other habitats and species in the landscape which are less dependent on natural processes but would be affected by change. In addition, our understanding of ecological relationships, between habitats, between species, and between habitats and species, uses natural ecosystem function as its main reference point – we cannot explain these relationships without reference to natural ecosystem function.

Better integration of biodiversity objectives based on linked consideration of ecological relationships and natural function has benefits for the conservation of all habitats and species. It can provide the basis for clearer strategic direction at the local level, which allows greater progress to be made in attracting funds to implement measures. It also provides the framework for a holistic and sustainable approach to climate change adaptation for our native habitats and species complement. This said, there are many risks to consider and adverse consequences to be avoided. It is critical that we achieve integration without loss of resolution in our decision-making: we need to ensure that the needs of individual species are not lost in a greater focus on habitat function, and that the needs of individual habitats are not lost in a greater focus on habitat mosaics. We need an approach to integration that demonstrably safeguards and restores all aspects of biodiversity.

The Convention on Biological Diversity defines the terms *in situ* and *ex situ* conservation in ways that have relevance to establishing a more integrated perspective. ***In situ* conservation** primarily relates to the conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings. ***Ex-situ* conservation** relates to the conservation of components of biological diversity outside of their natural habitats. Article 8 of the Convention requires that contracting parties promote the protection of ecosystems, natural habitats and the maintenance of viable populations of species in natural surroundings. Article 9 requires that, as far as possible and as appropriate, ***and predominantly for the purpose of complementing in-situ measures***, contracting parties adopt measures for the *ex-situ* conservation of components of biological diversity. This provides a general ambition around which we can build a more integrated framework for biodiversity objectives:

'***to promote the protection and restoration of natural ecosystem function where this is possible and desirable'***.

The remainder of this document explores how we might best approach ecological relationships and natural function to realise this ambition, embedding adequate safeguards to ensure we build on what remains of our natural heritage.

3.2 Considering ecological relationships

Building the characterisation of ecological processes and relationships into biodiversity decision-making allows us to cut through the artificial boundaries that have developed between biodiversity specialisms and been embedded in conservation strategies. These boundaries exist between different habitat types, between habitats and species, and between species, but the relationships between habitats and species are perhaps easiest to convey and are discussed below. Relationships between habitats are difficult to characterise without explicit reference to natural function, and these are discussed in the following section (3.3).

In considering the conservation of an individual species there is a natural tendency to think of a species' optimal habitat conditions and not necessarily the broader habitat mosaic within which those conditions are best provided. This can lead to assigning high importance to preserving existing environmental conditions at a site, which may provide extensive optimal habitat for a particular species but not the habitat needed for characteristic biological assemblages of the area. In restoration terms it can also inadvertently lead to a management focus on engineering optimal habitat conditions for the species in ways that do not meet the broader requirements of characteristic biological assemblages, which can also be expensive and unsustainable in the long-term. This can manifest itself through an unnecessary dichotomy between the expression of 1) habitat objectives and 2) 'habitat-for-species' objectives. It can also lead to tensions between different species objectives where the optimal habitat conditions of species differ, as they inevitably do at some ecological scale due to the evolutionary necessity of resource partitioning.

A more explicit focus on placing species in their broader ecological context provides the means by which the different needs of individual species can be resolved in habitat objectives that are capable of catering for characteristic species assemblages, including their rarities. This can be thought of as a '***habitat-led, species aware***' approach. This type of rationalisation is not without consequences. A shift of emphasis towards fitting individual species requirements into the broader ecological needs of biological assemblages can reduce the extent to which optimal habitat conditions are provided for a single species. This has implications for what we might perceive as an acceptable population size, or for exactly where in the landscape a species might find optimal conditions.

3.3 Considering natural function

Better recognition of ecological relationships in our biodiversity objectives is an important step but it cannot on its own resolve different perspectives about which habitat or species would best be conserved in particular locations or particular ways. Some sort of reference framework for decision-making is required which allows sensible judgements to be made about the balance struck between different habitats and between different species, and more generally between biodiversity objectives and wider societal needs. Natural function is an important reference point in the evaluation of local ecological circumstances, which can inform the balance struck in any given situation. It provides the basis for our understanding of ecological relationships between different habitats and different species.

Natural function can be a contentious concept, when associated with an idealised perspective of 'rewilding' biodiversity in which modern man is largely removed from a landscape. However, there are ways in which natural function can be recognised, valued, protected and promoted in a proportionate way, working within the legitimate constraints of any given landscape and grasping the opportunities that are available whilst safeguarding existing biodiversity. This can be thought of as a '***natural process-led, habitat aware***' approach.

The first step in such an approach is consistent and explicit ***characterisation*** of natural function. Understanding the extent to which different habitats and species currently operate according to natural abiotic and biotic processes (including their natural variation over time), and how they are likely to be affected by climate change, is a pre-requisite for making informed decisions, whatever those decisions may be. This requires some sort of common evaluation framework to ensure we are comparing like with like across the various habitat and species interests. This framework has to capture the most important natural processes but remain sufficiently simple to operate effectively and in an understandable way. Figure 3.1 identifies five types of natural process (or elements of natural function), which can be evaluated independently against a gradient of naturalness to build up a structured picture of natural function. These elements are governed by the intrinsic properties of the landscape and its received climate: geological and soil types, topography and patterns of rainfall and temperature.

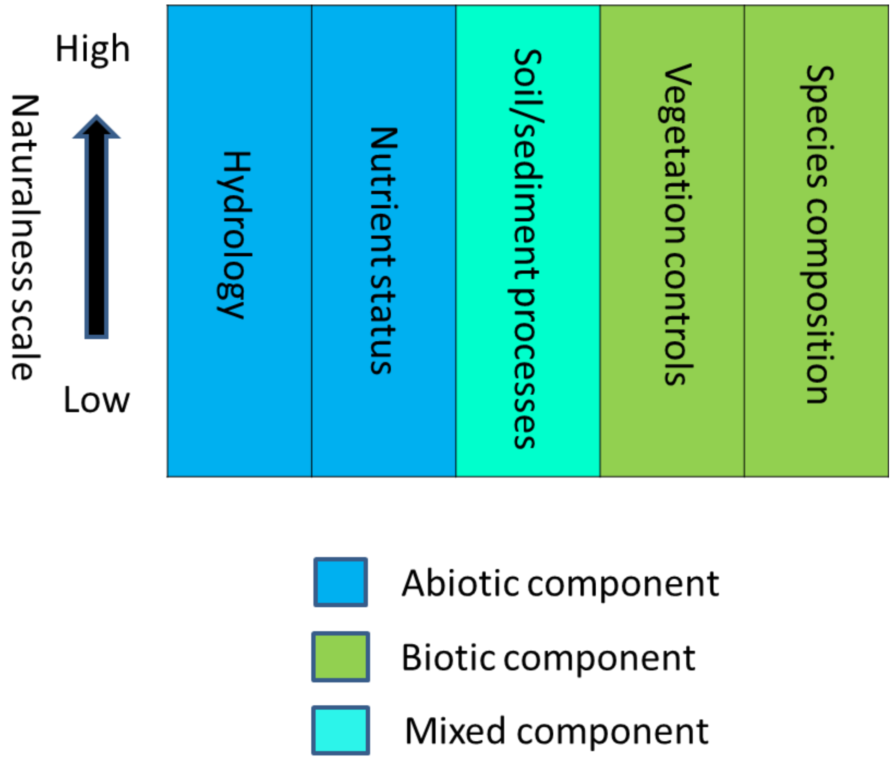


Figure 3.1 Natural process framework (applicable to a whole habitat resource or an individual site)

- ***Hydrology*** – The pathways that water takes through catchments are a fundamental determinant of habitat and species patterns. This holds true for all habitats, of varying levels of wetness from open water to habitats such as dry heath, and their associated species assemblages. These pathways not only determine wetness patterns in the landscape but also the natural hydrochemistry of water and hence soils (alkalinity, trophic status etc.), which has a fundamental bearing on habitat and species patterns Natural hydrological pathways form a critical foundation of the natural habitat template in landscapes, and are therefore central to a more integrated framework for biodiversity objectives. Disruptions to natural hydrology include drainage, abstraction, water diversion, flood defence and pathway blocking by urban and industrial development and associated infrastructure.
- ***Nutrient status*** – The availability of plant macronutrients shapes natural ecosystems. Nutrients are naturally generally scarce (and still are in some semi-natural habitats) relative to their availability in developed landscapes. Increased availability through regular cultivation and heavy fertilisation of soils, the disposal of sewage and industrial waste and atmospheric pollution and deposition has severe detrimental effects on aquatic, wetland and terrestrial ecosystems. The many species of natural habitats that have evolved to capture scarce nutrients in an efficient way are out-competed by a smaller number of species that have evolved to exploit natural spikes in nutrient availability (e.g. animal dung at various spatial scales), changing and simplifying foodwebs and reducing natural species diversity. Inappropriate approaches to deal with this excess of nutrients can also result in further imbalances and unintended consequences.

- ***Soil/sediment processes*** - This is a more heterogeneous group of processes covering both soil health (organic matter content, soil microbiota) and patterns of sediment erosion and deposition in the landscape. Terrestrial semi-natural habitats rely on naturally functioning soils, whilst aquatic habitats are fundamentally shaped by the movement of sediments (creating diverse habitat mosaics in river, lake and coastal ecosystems). Natural function in this context relates to the freedom of soil and sedimentary processes to build and shape characteristic habitat mosaics with characteristic levels of dynamism – the formation of peat in water-logged conditions (a slow, stable process), the development of humic woodland soils, the lateral erosion of river channels and creation of exposed shingle banks (a highly dynamic process in many river types), and the continuous formation of sand dunes (strong dynamism, requiring a supply of sediment for new dunes to maintain the full range of vegetative successional stages). In semi-natural grasslands soils are known to have high fungal-to-bacterial ratios while the reverse is true in heavily fertilised intensive grasslands (Defra 2012), and this is important in sustaining characteristic plants and animals (e.g. symbiotic associations with the root systems of most plants, the most well-known being orchids and trees).
- ***Vegetation controls*** – This largely relates to the nature and intensity of biological controls on vegetation succession, over and above the abiotic controls on vegetation development outlined above. In natural ecosystems native herbivores play a key role, controlled at levels determined by resource availability, native predators, and factors such as disease (Vera 2000). In modified landscapes vegetation control is determined by livestock grazing, cutting (e.g. in woodland and scrub management) and burning (e.g. on upland moorland). The high intensity of some types of human control (e.g. intensive forestry) is highly detrimental to the expression of naturally functioning habitat mosaics. Alternatively, human controls can be designed to mimic natural controls in ways that contribute to habitat mosaics, e.g. managing hedges to mimic scrub in the landscape. Low natural function in vegetation controls may result from intensive human management (heavy livestock grazing or cutting), or excessive grazing and browsing by native species due to a lack of population control by native predators (which have been removed by hunting), or damaging levels of grazing or disturbance by non-native species.
- ***Species composition*** – In natural ecosystems species assemblages are shaped by the habitat mosaics formed by the four types of natural process outlined above. They are therefore in large part a reflection of the naturalness of those processes. However, in addition to impacts on these natural processes non-native species have the potential to cause major direct disruption to native species assemblages. These impacts can be as great as any other impacts on natural function (Strayer 2010), and can sometimes extend to effects on physical habitat provision (e.g. river bank destabilisation from signal crayfish and Chinese mitten crab). Also included under this element of natural function are direct biological manipulations of native assemblages, which would include human activities such as the selective removal of tree species from native woodland, and the removal of unwanted native fish species and the stocking of quarry fish species (sometimes non-native) in freshwaters.

This is not intended to be an exhaustive set of natural processes, but it covers key elements in terms of developing a shared understanding of natural ecosystem function. Biological connectivity was originally considered within the project as a further pillar in Figure 3.1, related to habitat fragmentation and barriers to dispersal and colonisation (Lawton *et al*. 2010). Whilst it is a critical conservation issue it is arguably less important to articulate through this schematic. Biological connectivity is however an important recurring theme in this report and is central to biodiversity decision-making. Importantly, connectivity is not only a spatial issue but also a temporal one – for instance, rare species are generally only abundant in old large trees on sites where there have been old large trees for many centuries. Fragmentation and connectivity are dealt with more comprehensively in the Ecological Networks Handbook (Natural England In Prep), where it is a key consideration in designing ecologically resilient landscapes.

The schematic in Figure 3.1 can be operated at the level of the whole resource of a given habitat type, or alternatively at a site-level for a given habitat type or (potentially) a larger scale habitat mosaic. It allows the different aspects of natural function to be considered independently, making it easier to focus in on aspects where lack of natural function may be most important to integrating biodiversity objectives. A key separation is between: 1) abiotic processes that determine where in the landscape a particular habitat type (and hence species assemblage) can potentially develop, and 2) biotic processes that determine where it does actually develop. In management terms, natural abiotic processes provide a set of habitat and species assemblage ***opportunities***, from which management ***choices*** to meet defined objectives can be made through vegetation controls (often mediated by animal species).

This structuring also allows the concept of rewilding to be placed into context. Rewilding can be portrayed as a restoration objective with high levels of naturalness across all five types of natural process. In some specific localities this may be a realistic conservation goal, but we need a framework that allows any level of ambition to be expressed in relation to any of the 5 types of natural process independently of each other, depending on circumstance. For instance, it may be desirable to restore more natural hydrological function and/or nutrient status to an area, whilst maintaining existing low intensity agricultural grazing or woodland management. Figure 3.2 shows how such partial restoration of natural function might be expressed.

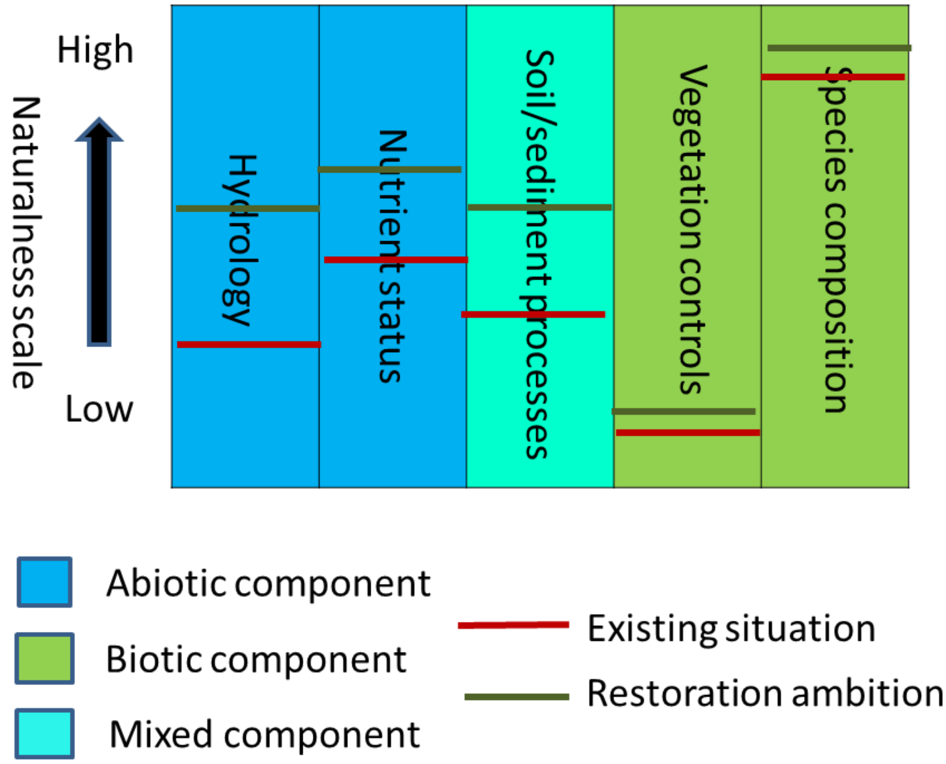


Figure 3.2 Illustrative judgements of practical and desirable restoration of individual elements of natural function.

Whilst developing a robust evaluation system of this type would take considerable time and resource, it is possible to apply this broad framework in a subjective but informed way to help characterise the existing habitat resource and the scope for improved natural function. This has been attempted in the accounts of habitat types and their species assemblages given by Natural England specialists in the appendices, which are discussed collectively in Section 4.

It is worth noting that there is no consistent relationship between: 1) the evaluation of habitat and species using this natural process framework, and 2) the evaluation of habitat, species or site ‘condition’ as used in the assessment of protected sites and priority habitat and species. There are close affinities between the two for some habitats (e.g. open freshwaters), where natural function is particularly important and therefore strongly embedded in conservation rationale and hence condition assessment. Other habitats and a range of individual species can exist in wide-ranging degrees of natural ecosystem function, and if conforming to ‘condition’ targets (for SSSIs or priority habitats and species) will be assessed as favourable. For instance, optimal habitat conditions may have been created for a species (either by serendipity or targeted management measures) which are artificial in nature but support a large population – the species may be considered to be in favourable condition on account of the large population size.

4 How habitat types and species fit into a more integrated framework

4.1 Preamble

Accounts of the circumstances of different habitats and their species complements are provided in the appendices. These accounts follow conventional broad divisions of semi-natural habitat variation (woodlands, grasslands, open freshwaters etc.) and so will inevitably suffer from some of the problems that this report seeks to address. For instance, areas we define as a dry woodland at one scale may contain patches of mire at a smaller scale. For this reason each appendix is structured to focus on the integrating vehicles used in this report (ecological relationships and natural function). They also seek to integrate habitat and species perspectives, taking into account the general ambition of protecting and restoring species through naturally functioning habitat mosaics.

The text in this section of the report develops this integration focus by following a similar structure to the appendices and drawing out some important themes running through the appendix accounts. An additional sub-section (4.5) is included on the issue of 'developed land' with little or no semi-natural habitat, to highlight its importance to certain species in modern landscapes and help reconcile conservation efforts on such land with the broader promotion of naturally functioning habitat mosaics.

4.2 Ecological function and relationships

It is instructive to first consider how we define different habitats, because this helps to explain ecological relationships between them and their species complements in the landscape. Habitat definitions are couched in ways which reflect the dominance of abiotic or biotic processes in their natural occurrence and maintenance in landscapes.

- Some broad habitat types are defined by their **abiotic** characteristics, and biological descriptions add colour to that characterisation rather than define the broad habitat. It is clear from the appendices that these types of habitat, such as rivers, lakes, bogs, saltmarsh, sea cliffs and sand dunes, have a natural position in the landscape, strongly governed by abiotic processes that shape substrate conditions and dictate the development of vegetation. This position is dynamic and can change gradually or in an extreme way in response to infrequent natural events (e.g. storms).
- Other types of broad habitat, such as grassland and woodland, are defined by their **biotic** characteristics. These can naturally appear more or less anywhere in the landscape, because the differences between them are largely a product of variation in the degree of biotic control of the vegetation. The abiotic controls influencing which of these habitat types occurs in any one location are generally weak, except in extreme circumstances such as mountain tops where tree growth is inhibited. This said, abiotic factors are very influential in the specific character of the woodland or grassland habitat that can naturally develop in any one location in the landscape. So, biotic vegetation controls typically dictate whether a land area is covered in woodland or grassland, but abiotic processes naturally dictate whether a woodland or grassland is made up of species of wet or dry, or acidic, neutral or alkaline conditions.

In between these extremes lie heaths and some fens, which can only naturally occur in certain abiotic conditions but generally require biotic controls on vegetation to prevent succession to scrub and woodland. The specific abiotic conditions (e.g. soil types, hydrology) again dictate the specific types of heath and fen that occur in any one location.

Natural ecological relationships in the landscape are strong where abiotic controls (hydrology, soil type, topography, aspect) generate strong gradients in environmental conditions and hence vegetation types. Spatial zonation of stages of hydroseral succession are a classic example, where a hydrological gradient from open water to dry soil generates a natural sequence of vegetation from fully aquatic, through swamp and fen (wooded or open), to wet then dry grassland, heathland or woodland. Strong environmental gradients can also be found on mountain sides, where differences in temperature, exposure and soil depth generates sequences of vegetation from closed woodland to open woodland and scrub up to heath and bog, interspersed with bare ground. These natural, and relatively predictable, geographical relationships are still subject to dynamic change – vegetation succession in hydroseres, short-term fluctuations in weather and long-term trends in climate. The natural habitat mosaics these situations create tend to be complex, diverse, dynamic and relatively naturally sustainable, with strong transitional conditions between conventionally defined habitats. This provides excellent conditions for supporting a rich array of species within their natural habitat niches.

In the absence of strong abiotic gradients, the natural spatial relationship between open, scrub and wooded habitats can be thought of as unpredictable, governed by variations in natural grazing pressure (itself subject to variations in predator pressure and disease), fire, wind-throw of trees etc. Under natural conditions (at times when humans played a more balanced role in ecosystems), at large scales there is likely to have been a mixture of open, scrub and landscapes with trees (e.g. Vera 2000), sufficient to satisfy the needs of different components of the characteristic biological assemblages to a greater or lesser degree. The precise balance and spatial pattern of these habitats would vary over time as the dynamics of vegetation controls change conditions. This dynamic change is an integral part of replenishing and maintaining natural seedbanks across the landscape, as each of these habitats generates new progeny (seeds, eggs, clones) in its turn at any one location.

The appendices demonstrate the general importance assigned to small-scale habitat mosaics within individual habitat types. This small-scale complexity is vital for the full complement of species within the landscape. Natural function is key to this complexity – for instance, natural processes in woodlands generate a mixed tree age structure, open and closed canopies, old growth features and saplings, varying humidity levels, decaying wood and rich humic soils, providing the conditions for diverse lichen, bryophyte and fungal assemblages, and a diverse understorey of herbs and shrubs . These are all attributes that are critical for wildlife, providing nesting and breeding opportunities for invertebrates, birds and mammals. In mires, vegetation naturally develops structural complexity over time (e.g. Plate 4.1), which generates variation in small-scale conditions – hummock-forming *Sphagnum* species such as *S. capillifolium* create microtopography, allowing pools to form in plateau areas, whilst runnels and drier areas on gentle slopes provide the opportunities for a wider diversity of niches and their associated flora and fauna.

Plate 4.1 Structural vegetation complexity in a naturally functioning bog.

The relationship between this small-scale habitat variation and formally defined habitat features (e.g. SSSI features, priority habitats) is variable. Habitats that are considered formal features in their own right nest within other habitat types, for example small patches of wet and/or dry heath occurring in naturally functioning acid woodland (e.g. Plate 4.2). River habitat is an interesting case in point, where small-scale habitats (such as riffles and pools) are an integral part of the formal habitat feature, but exposed riverine sediments are additionally recognised as a habitat feature for a specific assemblage of invertebrates.

Plate 4.2 Nesting of some habitat elements (including SSSI features) in a naturally functioning acid woodland.

Some elements of natural habitat mosaics have had less recognition as explicit habitat features in their own right (as opposed to habitat for particular species or assemblages). Chief amongst these are bare and disturbed ground and scrub. Whilst often of low intrinsic botanical interest, these habitat elements are highly important to fauna such as invertebrates and birds. Within conventionally defined semi-natural habitats such as grasslands and heathland they have historically been viewed as features to reduce in extent. This is partly driven by cultural management perspectives which have tended to look negatively on disturbance as a feature in typically closed vegetative communities, and to regard scrub encroachment as a threat to biodiverse open habitat and its associated management by grazing. The fragmented nature of some of our most precious semi-natural habitats is a further factor, where patch size may be too small to easily accommodate scrub and bare ground. Outside of conventionally defined semi-natural habitats scrub and bare ground can be abundant, so their inclusion within semi-natural habitats has perhaps been seen as a low priority (putting them at risk of loss from development or agricultural management).

All this said, in certain contexts these generally low-profile habitats are valued as explicit habitat features. Bare ground and bare rock is recognised as a specific habitat feature where it occurs naturally in response to abiotic process (rather than biotic disturbance), such as exposed mud in estuaries (Plate 4.3), exposed gravel shoals in rivers (Plate 4.4) and on slopes (namely rocky slopes and scree). In the same way, scrub is arguably more universally valued as a habitat feature where its extent is controlled by natural processes, such as in the dynamic river habitat mosaic of active shingle rivers. Elsewhere, some types of botanically species-rich scrub are also valued as important habitats in their own right, for example juniper scrub.

Plate 4.3 Exposed muds in a natural saline transition zone of a river (at the estuary head).

Plate 4.4 Exposed gravel and cobble shoals in an upland river.

In natural ecosystems, disturbed/bare ground would naturally develop around watering holes where wild animals congregate (rivers, lakes, ponds and pools), and where natural abiotic processes (erosion, exposure, fire, natural water-level fluctuations, wind-throw of trees etc.) create disturbance. Many of our annual plant species and invertebrate species have evolved to exploit such conditions. Such plants (‘ruderals’) tend to be annuals, with high dispersal capacity and/or have long-lived seeds that can wait for infrequent disturbances to occur, whilst animals exploiting this niche are often ‘r-selected’ (small-bodied, high reproductive rate, highly mobile and dispersive) to make sure that they take maximum advantage of the often limited opportunities that arise and the high disturbance levels prevailing. However, bare ground is also necessary for the recruitment or regeneration from seed of longer-lived perennial species over longer time-frames, especially in habitats such as grasslands and heathland, and in the generation of suitable ground temperatures for certain species.

Scrub forms part of the process of vegetation succession from grasslands to woodland, and can form climax communities in environments that are hostile to tree growth (Plate 4.5). It can play an important role in allowing natural tree regeneration by protecting young saplings from large herbivores. In a dynamic natural landscape it will come and go in different areas depending on variations in the level of grazing and browsing, as well as abiotic disturbances such as a river meandering across its floodplain, or periodic landslips on steep hill slopes. Wherever it occurs in natural landscapes, it plays a critical role in supporting a wide range of animal species, including butterflies and birds.

Plate 4.5 Scrub within an upland habitat mosaic.

In recent years, there has been increasing consensus that small amounts of these low-profile habitats are important components of the smaller-scale habitat mosaic of recognised semi-natural habitat features such as grasslands and heathland, as well as larger scale mosaics. This recognition extends beyond their botanical importance (e.g. bare ground for seed germination that introduces fresh recruits into valued plant assemblages) and into the needs of specialist fauna, and has been heightened by the need to accommodate priority species requirements more explicitly into habitat conservation (Mortimer *et al*. 2000, Webb *et al.* 2010). It is their occurrence as transitions within and between conventionally defined semi-natural habitat types, within habitat mosaics, where they are most ecologically important to many rare and declining species (e.g. Duke of Burgundy butterfly, *Hamearis Lucina)*. A suitable balance is needed, which will vary between different habitat types and situations, but perhaps the most important point for integrating biodiversity objectives is to recognise that a balance is the best outcome, and that this balance is easier struck in large sites or at landscape scale than in small fragments of highly valued and rare habitats.

The general parsimony of nutrients in the natural environment is a common feature of accounts in the appendices, dictating the functioning of foodwebs and the relationships between species and their habitats. At a small spatial scale high concentrations of nutrients can be important for the conservation of certain species, and a closer inspection of the nature of natural nutrient cycling is worth attention. Natural concentrations occur at the smallest scale in dungpiles from individual animals, which create a microcosm of biodiversity. At a slightly higher spatial scale, watering-holes can create accumulations of dung and therefore nutrient availability, which some annual plant species are adapted to exploit along with the associated soil disturbance. Larger scale accumulation can also occur, e.g. in coastal seabird colonies, as well as large-scale recycling, e.g. in saltmarsh habitat and in the natural recycling of marine nutrients to the land generated by migratory fish such as salmon (mediated in natural ecosystems by land-based predators).

In general modern human activities (agricultural and forestry fertilisation, domestic and industrial waste, atmospheric deposition) have swamped English landscapes with nutrients and the nuances of natural nutrient cycling have been lost, with adverse consequences for the many species adapted to exploit low nutrient conditions. Restoration of more natural levels and routes of nutrient cycling are critical to rebalancing ecological relationships between species with different nutrient strategies, and hence making space for all of our native species in the landscape.

4.3 Current level of natural function

This section focuses on the extent to which different habitats are currently located in natural positions in the landscape, and the extent to which they are functioning naturally according to the five pillars of natural function outlined in Section 3. The appendices include best judgements of the extent of natural function in the existing resource of different habitat types. The ‘existing resource’ has been interpreted loosely as semi-natural habitat recorded in the various priority habitat inventories. However, a different approach has been required for some habitats where the priority habitat inventory does not adequately represent the distribution of the whole habitat resource (e.g. rivers, lakes, trees and woodlands).

As mentioned in Section 3, the relationship between natural function and habitat condition (for SSSI habitat features, priority habitats, habitat for particular species) is not simple and depends on the nature of condition assessment – for some habitats there is a strong relationship between the two whereas for others it is possible (even likely) for habitat to be considered in favourable condition but with low natural function in various respects. Most biodiversity benefit can be expected when a habitat area is in favourable condition and is also functioning naturally within a broader naturally functioning habitat mosaic.

Not surprisingly, there is considerable variation between habitat types in the existing level of natural function. For some components of natural function (particularly hydrology), lack of natural function is often related to alterations in the geographical location of the habitat type relative to where it would be located under natural processes. Key issues associated with each of the five pillars of natural function are now considered in turn.

Hydrology

This is a major factor in the loss of natural function in landscapes. Drainage and flood defence schemes have reduced water tables and restricted seasonal flooding, nutrient and plant propagule transfer, eliminating the naturally functioning habitats that rely on these processes. In many cases the changes have enabled land use shifts to intensive agriculture or urban development, but in other cases the subsequent land-use has been of sufficiently low intensity to allow some of the components of the natural system to persist in the modified environment. For example, drainage may have altered the vegetation of one land area from fen to wet grassland or heathland, and another adjacent land parcel from wet grassland/heathland to dry grassland/heathland (e.g. Plate 4.6). Drainage of coastal and river floodplains has eliminated the natural mosaic of wet and dry habitats but has created grazing marsh, which may retain some of the species of the original habitat mosaic. All this has major implications for how the biodiversity importance of individual land areas is perceived. For instance, should a specific patch of land be thought of as a healthy dry heath or a degraded wet heath, or even destroyed woodland? Natural ecosystem function provides an ecological answer, but local constraints to restoration and other factors may dictate otherwise (see later sections).

Plate 4.6 A drained valley mire from which rush-pasture (a priority habitat) has been created.

Other losses of natural function are perhaps not so obvious and can operate at smaller spatial scales. For instance, drainage in woodland may have eliminated flushes and mire patches with no apparent change in the over-arching habitat type (e.g. acid oak woodland) but with the loss of critical elements of the smaller-scale habitat mosaic.

The impact of loss of natural hydrological function is not only felt by habitats at the specific locations where the modifications have occurred, but also at locations further down the hydrological pathways that are affected. It leads to damaging modifications to hydrological, nutrient and sediment regimes of downstream habitats, and affects ecosystem services such as flood management and drinking water quality (for example the effect of moorland gripping on the quality of drinking water supplies).

Overall, the amount of remaining habitat in England that is functioning naturally from a hydrological perspective is currently low, which has significant implications for delivering integrated biodiversity objectives. This said, recent trends towards hydrological renaturalisation (e.g. moorland grip-blocking, river restoration and natural flood management including coastal managed realignment) provide optimism for the future.

Nutrient status

There has been an enormous increase in the availability of nutrients in English landscapes over the past century, as a result of population increases, the development of sewerage systems, increased use of agricultural fertilisers and atmospheric nitrogen pollution. Extensive cultivation of old grassland since the Second World War has created large additional increases in nitrate losses to groundwater. Whilst there have been large resultant increases in the nutrient status of intensive agricultural soils, the nutrient status of remaining semi-natural terrestrial habitats has been less affected in relative terms. Even so, sufficient enrichment from various sources has occurred to contribute to biodiversity declines. Mechanisms of enrichment include direct agricultural fertilisation to boost yields, local drift from intensively managed land, broader atmospheric deposition and the oxidation of drained peat soils. Water-related habitats are highly connected to their catchments and so have suffered heavily from nutrient enrichment, with associated adverse effects on characteristic biological assemblages.

Conceptually there should be relatively few integration issues around the restoration of more natural nutrient status of semi-natural habitats as long as natural accumulations of nutrients (usually in dungpiles of various scale) are recognised and accepted. The objectives for habitats and their associated species can be accommodated by constraining nutrient availability to levels that reflect near-natural availability, to ensure that the many plant and animal species adapted to efficient scavenging of limited nutrients are adequately conserved. Some species evolved to exploit natural accumulations of nutrients have benefited from man-made nutrient enrichment in the environment, and some of these have particular biodiversity interest. Such species also thrive in habitats with natural levels of nutrient availability but not necessarily at such high population levels, so there is no real conflict of biodiversity interest as long as population targets reflect natural environmental carrying capacities.

Soil/sediment processes

There has been widespread disruption to natural soil processes as a result of practices such as drainage, ploughing and the use of agro-chemicals, associated with intensive farming, forestry and urban development particularly since the Second World War. These changes have affected levels of organic matter, soil carbon and soil microflora, as well as hydrology and nutrient status as outlined above. This has been associated with considerable loss of semi-natural habitats but more broadly has resulted in increased levels of soil erosion and compaction, which has led to changes to hydrological pathways through catchments and the enhanced delivery of rainfall, soil and contaminants to freshwater and coastal habitats. At the same time, engineering schemes and sediment management regimes (e.g. channel dredging) have restricted the natural movement of sediments in freshwater and coastal environments, leading to the loss of dynamic habitat mosaics.

Within the remaining semi-natural habitat resource, issues with the naturalness of soil and sediment processes are less pronounced than in the wider landscape, but they do exist. There are relatively few integration issues to be resolved compared to some other pillars of natural function, since the aim for most semi-natural habitats and their species would be to maintain or restore natural or near-natural soil processes. Conflicts can arise in respect of natural sediment processes, where the dynamic movement of rivers and coastal habitats can interfere with the maintenance of existing terrestrial and wetland habitats and their associated species, for instance the lateral movement of a river into a flower-rich floodplain grassland. Changes in soil processes associated with artificially modified hydrology are dealt with in the section on hydrological function above and are not considered further here.

Vegetation controls

Natural vegetation control by native herbivores has largely been lost from the English landscape. We have become accustomed to thinking of biotic controls on vegetation as solely human-mediated in nature, through agricultural and woodland/forestry management. The re-appearance of beavers in parts of the British landscape has been a reminder of the natural habitat engineering that native species can do. Heavily influenced by ecologists such as Tansley, we have come to think of the English landscape before the dominant influence of humans as being naturally cloaked in closed canopy woodland with very little open habitat. However, Vera (2000) has suggested an alternative theory where large herbivores from Aurochs to geese drove the system, maintaining large open areas with scattered trees and groves.

Native species of deer are now the primary remaining natural mechanism of biotic control of vegetation in England, but their grazing activity is insufficient to maintain open vegetation. Non-native species now play a considerable role – rabbits can maintain tight chalk grassland swards with very high botanical diversity, whilst non-native deer species add to the grazing and browsing activity of native species. The absence of natural predators, together with relatively low interest in wild herbivores as a human food source, can lead to high levels of grazing and browsing that prevents full expression of semi-natural vegetation. This is a particular problem in our woodlands, where high deer populations are suppressing the understory and preventing the development of young trees (Ward 2005).

For the most-part biodiversity conservation in England is dependent on human-mediated biotic controls on vegetation, determining the balance struck between open, scrub and wooded habitats. This dependency has grown as habitat fragmentation has increased and the ability of habitats to act as large-scale naturally functioning mosaics has declined (Hodder *et al*. 2005).

The lack of trees and shrubs in many English landscapes is a major issue in relation to naturally functioning habitat mosaics, and is particularly apparent in the uplands. Sheep grazing occurs across a wide range of semi-natural upland habitats, including moorland, valleyhead fens and bogs, stream and lake margins and rush-pasture. The intensity and prolonged nature of the grazing (over many decades) has suppressed natural tree and shrub growth and progressively depleted the upland seed bank. Moorland and moorland fringe is often perceived as naturally treeless, but the climatic control of tree and shrub growth appears to be much less influential than the influence of prolonged and heavy sheep grazing. This is often evident along the moorland wall, where the presence of trees and shrub can end abruptly at the boundary (Plate 4.7). This affects not only the existence of woodland and scrub habitat itself but also the role of scrub and trees in the natural functioning of other habitats, such as ghyll streams and the natural stabilisation of valleyhead mires (Mainstone *et al*. 2016).

Plate 4.7 The effect of the moorland wall on the occurrence of native trees (note in particular the denuded ghyll).

Within the sphere of open upland habitats, sheep grazing has also played a major role in the loss of moorland habitat mosaics to acid grassland, alongside gripping and burning practices that have dried out soils and increased access by sheep.

All this is reflected in the low levels of naturalness of vegetation controls indicated in the appendices. This situation generates simplification of natural habitat mosaics and a loss of dynamism in the balance between different habitats.

Species composition

The direct impact of non-native species on our habitats and their characteristic species assemblages is increasing rapidly. There are examples of dramatic invasions in most habitats: signal crayfish in freshwater habitats, rhododendron, non-native deer and grey squirrel in woodlands, and cotoneaster species in calcareous grasslands. Non-indigenous diseases are also having devastating effects on native species, including crayfish plague carried by signal crayfish and the multitude of imported diseases of native tree species. Direct human manipulations of species assemblages are also common: centuries of woodland management which favours some species and selectively removes other native tree species, selective planting of commercial tree species (non-native and native) in woodlands, and selective removals of native fish species and introductions of quarry fish species in freshwaters for fishery purposes. These activities not only affect species composition directly but also the genetic diversity of native populations, which can have consequences for the long-term resilience of native species (e.g. disease resistance, ability to adapt to changing conditions). The levels of naturalness recorded for this pillar of natural function are consequently relatively low.

Whilst these issues are major conservation concerns, they generally create few integration problems for biodiversity objectives. The ambition across all semi-natural habitats, and for the protection of native species generally, is for the effective control of non-native species. The challenge facing biodiversity conservation generally is the feasibility and cost of control in the face of ever-increasing numbers of non-native species.

Some species-specific conservation issues may arise as a result of non-native species that support rare native species. An example is horse chestnut *Aesculus hippocastanum,* which originates from the Balkans and was widely planted in England as an ornamental tree in parklands. Its propensity to form wet internal rot hollows and often prolific bark seepages make it a highly suitable host species for many native saproxylic diptera which are able to use these wet substrates as larval habitats. The Western wood-vase hoverfly *Myolepta potens* was re-discovered in the UK (after a declaration of extinction) from a number of veteran horse chestnuts. The original host tree species of *M. potens* in the UK are unknown but may have been beech or ash which provide similar microhabitat but in less abundance.

It should also be noted that natural processes themselves will lead to the establishment of new species in the UK as a result of a warming climate, Species that are native to northwest Europe but at the northern limit of their distribution will extend their natural range into the British Isles. This can be considered a normal part of natural ecosystem function and necessary for the conservation of these species as the southern parts of their range are squeezed. Such species are more closely linked to our native flora and fauna through past oscillations in climate and historical connectivity between the British Isles and the European mainland, so the effects on our current native species complement are likely to be smaller than the effects of non-native species that have evolved in distant geographical locations. In contrast, some of these far-field non-natives, many of which are known to be potentially highly invasive in the UK, will benefit from more favourable environmental conditions in a changing climate and are more likely to be problematic.

4.4 Restoration of natural function

This section focuses on the extent to which restoration of different elements of natural function is practical and desirable in different habitat types. The appendices include best judgements of the scope for such restoration, either by modifying conditions within existing areas of semi-natural habitat, or by creating new semi-natural habitat with natural function in mind. In making these judgements a future habitat resource has to be envisaged that may include more land area, or different land areas, than in the existing semi-natural habitat resource.

This has been a very difficult evaluation for biodiversity specialists to make, and the views expressed can only be regarded as a broad indication of the nature and scale of possibilities. The process of evaluation has revealed philosophical tensions: static versus dynamic perspectives of biodiversity value; conserving what remains versus what could exist; and differing levels of optimism about what might be achievable. What is possible is ultimately dictated by a wide range of local factors, relating to both biodiversity and socioeconomic considerations.

For habitat types that are defined largely by abiotic characteristics and where restoration of natural function is an important part of existing conservation strategy (e.g. freshwater, coastal and upland habitats), there is high optimism about the scope for restoration of natural function and good consensus on the benefits to species associated with those habitats. This is at least in part linked to the increases in natural capital and improved ecosystem services to be gained by such restoration, and the consequent support from many partners and stakeholders. Notwithstanding this optimism, there are considerable socioeconomic constraints and challenges, including potential adverse effects on habitats and species in their current locations, such that a strategic perspective is required involving long timescales and careful planning.

Terrestrial wetland habitats such as bogs and fens are in a situation that is more akin to freshwater, upland and coastal habitats. They have been squeezed out of landscapes by extensive drainage and require restoration of natural hydrological processes in targeted areas to restore the habitat resource. Their restoration is intimately linked to the restoration of freshwater habitats.

For the habitat types defined largely by biotic characteristics and where restoration strategies have historically been more driven by maintenance of traditional management methods (e.g. grasslands, heathlands), there is generally more conservatism in perspectives on restoring natural function. This is partly because fewer direct benefits to those specific habitat types can be envisaged, such that a more holistic perspective on habitat and species objectives is required to favour restoring natural function than has previously been the norm. It is also partly because the assessment requires a different mental picture of reference conditions to be adopted; landscapes have to be envisaged in which habitats are located where they might develop under natural processes, rather than where they have been in the recent past.

Woodland habitats are in a somewhat hybrid situation. Some woodlands are managed along non-intervention lines and it could be argued are well aligned with the promotion of natural ecosystem function. Even in these woodlands a broader perspective on natural function may be required to create more emphasis on addressing (largely historical) land drainage works that have eliminated natural small-scale freshwater wetland features from the habitat mosaic (flushes, springs, pools, runnels and streams). Wetland woodland types (alluvial forest, alder and willow carr) have been lost from the landscape along with other wetland habitats as a result of larger scale drainage activity, and there is considerable scope for their re-creation as part of broader naturally functioning habitat mosaics. Woodlands with traditional vegetation management regimes are often associated with particular species that have benefited greatly from the specific form of management; for example coppice woodland and the dormouse and heath fritillary. In these woodlands there are attempts to mimic some key elements of natural function (e.g. glade formation, rotting fallen wood), but targeted restoration of hydrological pathways within them would again greatly help the full expression of the natural habitat mosaic. This need not greatly affect existing biodiversity interest if undertaken selectively on limited areas of individual woods, bearing in mind the high biodiversity importance of old growth woodland (e.g for fungal assemblages) when selecting restoration areas.

Overall, restoration of nutrient status and native species complements (e.g. by removing non-native species) results in the least potential conflicts between the objectives of different habitats and species. Hydrological restoration (particularly through targeted reversal of land drainage), restoration of natural sediment processes (river restoration, restoration of natural coastal processes), and changes in the level and nature of biotic vegetation controls (affecting the balance between open, scrub and wooded habitats) have the most potential to generate conflicts between biodiversity objectives.

A critical biodiversity issue when considering the scope for restoring elements of natural function in a given area is the existing biodiversity value of the land. Restoring natural function may change the habitat type and its assemblage in that area (e.g. by making it wetter, less nutrient-rich, or less intensively managed), with consequences for any habitats and individual species it currently supports. Wet heath may revert to valley mire, and neutral grassland may revert to scrub or woodland. In practice the changes need not be this stark, parcels of land within a larger land area may change their habitat character with other land parcels remaining unchanged.

In general terms, in seeking to restore natural function it is best to avoid instances where high quality examples of semi-natural habitats would be affected, unless there is sufficient confidence that restoration measures would result in a net benefit and the process of ecological change does not risk elimination of rare species or habitats that are characteristic of the locality. The best opportunities for shifting the levels of natural function within a habitat resource largely relate to degraded examples of the habitat, or to land areas currently outside of the habitat resource where the habitat can be recreated. In short, restoration and recreation of semi-natural habitats is the obvious focus for restoring natural function.

Restoration of natural function may not change the defined habitat type of a land area, but rather alter the smaller scale habitat mosaic within it (e.g. restoring parcels of mire and flush within a particular woodland or grassland habitat type). This will depend on how the habitat is typed for management purposes: the higher the resolution of habitat types, the more likely there will be a change in defined habitat type. This argues for less resolution of detailed habitat types in management decision-making, and for a framework for defining and evaluating habitats that works at multiple spatial scales.

Reversing habitat fragmentation by creating larger spatial units of semi-natural habitats within mosaics is a critical factor in restoring key elements of natural function. This helps to create conditions for restoring natural hydrology and some level of natural vegetation control (for instance, glade formation in woodlands). It also makes individual spatial units more self-sustaining in the habitats they can provide, and therefore more resilient to management changes in the broader landscape. This said, many of the practical opportunities to restore elements of natural function are on a smaller scale, for instance naturalising an individual hydrological pathway in a large site or a wider landscape.

Trees and shrubs in the uplands provide a good illustration of some of the restoration issues that need to be addressed and the biodiversity synergies and conflicts needing to be resolved. Whilst the true climatic limit of native tree and shrub growth in the English uplands is still a matter of considerable debate (see Appendix G for further explanation), which has been complicated by the effect of intense and prolonged sheep-grazing as well as high numbers of deer, there is considerable scope for re-establishing a more natural mosaic of open, scrub and wooded habitat in the uplands, including open areas with scattered, open-grown trees. The degradation of blanket bog and associated ghyll erosion cause by past drainage has cause considerable loss of habitat condition and decline of characteristic species assemblages. This has created momentum for restoration and at the same time has reduced (although not eliminated) the risks of unintended damage to existing biodiversity from restoration of more natural function.

A priority for putting trees and scrub back into upland landscape is in ghylls, where soils can be stabilised and the stream habitat mosaic can be restored through riparian tree cover and the supply of leaf litter and woody material. Further opportunities exist all along the moorland wall, where natural recolonization from areas with trees and shrubs below the wall can create a readily sustainable habitat mosaic of open, scrub and wooded areas, maintained by more natural (low-intensity) grazing. High profile species beneficiaries of such restoration are Atlantic salmon and brown trout, as well black grouse (Warren *et al*. 2013), all of which can play an important role in the local economy. However, a much wider range of species would have their natural habitat niches reinstated (e.g. Mainstone *et al*. 2016, Kennedy and Southwood 1984).

Biodiversity conflicts arising from such restoration in the uplands that need to be addressed include potential effects on priority bird species such as curlew, redshank and snipe, which are at risk of increased predation pressure from the use of scrub and trees by corvids and raptors. Whilst this can be seen as a return to more natural predator pressure associated with a more natural landscape, there is a wider natural function perspective. Highly unnatural levels of prey availability caused by the release of large numbers of reared gamebirds affects the prevalence of avian predators in the uplands - increasing shrub and tree cover in the wrong areas may focus unnatural predator pressure on priority bird species. At the same time, hydrological restoration in the uplands will be improving and extending habitat conditions for these wading birds, which should increase population levels and counteract losses to predators. It may be possible to agree less intensive release regimes for reared game birds in some localities, as has happened with game-fish stocking regimes in English rivers (where many fishery owners are now placing a greater focus on natural recruitment and 'wild' fisheries). There may also be a need for active control measures to be taken on corvids to maintain predator pressure at near-natural levels. More generally, biodiversity conflicts associated with a decline in habitat extent for plants and invertebrates of open habitats can be reconciled by considering the scale and patchiness of tree and scrub restoration in the landscape. Open habitats would still be prevalent in the uplands, providing all of the habitat opportunities they do currently.

Overall, the perceived limits on the scope for restoration of natural function outlined in the appendices have much more to do with judgements of practical constraints than potential biodiversity disbenefits. Considerable scope is indicated, even though substantial local evaluation and negotiation is needed to realise the potential and manage any significant biodiversity risks.

4.5 Recognising the importance of 'developed land'

Despite the large biodiversity losses associated with intensive human activities 'developed land' (taken to mean any land which is not under semi-natural vegetation) can support a range of priority species, providing refuge areas where naturally functioning habitats have been lost and sometimes extending habitat opportunities for certain species. This includes species associated with low-profile and (generally) spatially limited components of naturally functioning habitat mosaics such as bare/disturbed ground, scrub and the ecotones at the edges between habitats.

Arable land creates extensive soil disturbance for annual plants and the invertebrate species that rely on them, as well as predatory invertebrate species such as rove beetles. Conifer plantations enhance populations of certain species, artificially extending their geographic range in some instances (e.g. crossbill, *Loxia curvirostra*). The quarrying of aggregates in floodplains has created extensive gravel pits which, along with the creation of artificial reservoirs, have greatly boosted populations of waterfowl and waders. The quarrying of limestone has extended the range of habitats such as calcareous grassland in some areas. In urban areas, gardens, parks and even buildings provide wildlife opportunities, whilst landscaped parkland in the countryside creates even greater opportunities.

The biodiversity value of developed land largely resides in small-scale 'land-sparing'. Where managed appropriately, hedges can form large linear networks of permanent scrub, acting as havens and conduits through the landscape for some species. Grazing marshes include extensive ditch networks that provide refuge for at least some of the species that have lost their natural wetland habitat mosaics. Conifer plantations have grassy rides and may have broad-leaved tree buffer strips. Highways have verges which can be botanically diverse, with scrub and trees forming a further linear habitat mosaic. Given that developed land has been developed primarily for commercial returns, these opportunities can provide significant biodiversity benefit, including as corridors between larger semi-natural habitats areas.

The biodiversity value of individual trees in developed landscapes is often overlooked because they do not form part of a woodland. In a natural woodland system, veteran trees and wood decay are key features, representing long term stability in both time and space. Individual trees in the wider landscape may be associated with defunct wood pasture systems, designed historic parklands and hedgerows. Those trees may be veteran and contain micro-habitats in rotsholes, snags and other veteran features, which provide habitat for wooddecay species, as well as for holenesting birds and some bat species.

In intensively managed landscapes, the only structural habitat features are contained in hedges and these may be the only places where some species can persist (Newton 2017). Alongside rivers and streams, riparian trees provide shading, woody debris in the channel, and their root systems play an important role in shaping fine-scale river habitat mosaics. Woody material is a habitat in its own right, the leaf litter and large woody debris offering a food source and shelter and generating dynamic small-scale habitat mosaics. Tree cover is an important mitigation measure against climate change both in riparian and urban situations.

Measures related to 'developed' land are critical to improving the connectivity between semi-natural habitats, and in extending habitat provision for a wide range of species. We need to make the best of the biodiversity potential of developed land whilst not hindering the restoration of naturally functioning habitat mosaics where this is possible and desirable.

5 Relationships with other objectives

5.1 Preamble

Developing a shared understanding of conflicts and synergies between biodiversity and other objectives is a critical part of local decision-making. This section seeks to provide brief accounts of integration issues in relation to a range of other objectives. Addressing potential conflicts and seeking synergies is the art of the possible. In some cases there will be win-win solutions whilst in others difficult choices will need to be made. Where compromise is needed, the precise balance struck between biodiversity and other objectives will vary from place to place, informed by the statutory status of different features in the landscape. In all cases, a transparent evaluation of biodiversity and other objectives is needed to ensure that the most appropriate outcome is sought. Open minds and a long-term perspective will provide the greatest opportunities for synergies.

As part of this discussion it is worth clarifying the treatment of the concepts of 'intrinsic appeal' and 'cultural value' in relation to biodiversity objectives, since these terms have long been associated with the selection of biological SSSIs and may therefore be considered an inherent component of biodiversity decision-making.

Intrinsic appeal

Many semi-natural habitats and their component species e.g. bluebell woods, flower-rich hay meadows, autumn flocks of waders on estuaries, clearly have high intrinsic appeal. Intrinsic appeal was listed by Ratcliffe (1977) as one of several secondary criteria for site assessment for SSSI status. However, although it is clearly an important aspect when considering the overall value of nature or wildlife to society, it has never been further developed in respect of statutory wildlife site assessment. Bainbridge *et al*. (2013), in the revised rationale for the selection of biological SSSIs, concluded that the criterion is inappropriate as part of a scientific evaluation of a site's biodiversity or nature conservation value, and should no longer be considered in the site selection process.

Cultural value

Many semi-natural habitats have had a long association with a particular form of non-intensive land-use which has sustained their wildlife value. Examples might include hay meadows, subject to hay cutting and grazing by livestock, and bluebell-dominated coppice woodlands. Their wildlife value is an accidental product of economic necessity, with grasslands providing fodder for livestock and woodlands and wood pastures supplying timber products. In such cases, an argument can be advanced for valuing the continuation of a particular form of traditional land management in its own right, quite apart from the fact that it also sustains high value habitats.

The cultural value of traditional management systems is not used in wildlife site assessment although the management may be embedded in the conservation objectives for semi-natural wildlife sites (such as in Views About Management, (VAMs), provided for SSSIs). However, 'Recorded history' was listed by Ratcliffe (1977) as a site assessment criterion and this would probably cover long-term continuity of a particular type of management, especially if well-documented. This aspect is generally taken into account in comparative assessments of sites, albeit as a secondary criterion. Bainbridge *et al* (2013), conclude that the value of recorded history as an evaluation criterion is little changed, and they continue to advocate the use of this as a criterion, with the caveat that SSSIs should not be chosen on the grounds of recorded history alone.

Given the above, in this report both intrinsic appeal and cultural value of wildlife habitats are treated as aspects of landscape character and cultural heritage when arriving at land use and land management decisions for a locality (see Section 5.4).

5.2 The role of natural capital and ecosystem services

Natural capital provides an over-arching framework within which all of the environmental objectives for an area can be considered. Ecosystem function is a fundamental characteristic of natural capital, and underpins the ability of natural capital to provide multiple ecosystem services. The five elements of natural function outlined in this report (Section 3) are key elements in terms of the condition of natural capital, supporting ecosystem services. This is reflected in Natural England's review of Natural Capital Indicators project (in progress). Potential indicators for the quality of natural capital relate to: hydrology (e.g. naturalness of water levels, flows, flooding); soil/sediment processes (e.g. soil carbon, soil biota, depth, nutrient and chemical status); species composition (naturalness of the biological assemblage, e.g number of trophic levels and community composition in each); vegetation controls (e.g. extent of bare ground, surface vegetation roughness, plant growth rate) and nutrient status (e.g. of fresh and marine waters).

Individual ecosystem services differ in the extent to which they benefit from the restoration of natural ecological function. For example, the restoration of natural hydrological processes on bogs, enhances carbon sequestration and global climate regulation. At the other end of the spectrum, natural function has been highly modified to maximise food production from intensive agriculture. There are lots of synergies in terms of natural function underpinning multiple ecosystem services. This is especially true for regulating services, with examples on regulating flooding, water quality and water supply given in the sub-sections below.

Cultural ecosystem services, such as wildlife watching, exhibit the same range of relationships with natural function as species and habitats do. Whilst many such experiences will be enhanced by the maintenance or restoration of natural function, supporting species populations as explained in this report, modification of natural function can increase some species populations (e.g. birds in estuaries with nutrient enrichment). Whilst this may enhance a particular cultural experience, an understanding of the combined effect of such modifications on biodiversity and associated natural capital, and on the combined effect of restoring elements of natural function, is needed to achieve a suitable outcome. Conflict mainly arises where landscapes and ecosystem processes are highly modified to provide just one provisioning ecosystem service. Extractive provisioning services such as fisheries, if not managed sustainably, can also profoundly modify natural function.

5.3 Geology

A wide range of sites are notified for their geodiversity interest in England. Although geological and geomorphological features may be scientifically important for a number of reasons (e.g. for their stratigraphy, palaeontology, mineralogy, or coastal geomorphology), their conservation and management needs can be considered by assigning them to one or more of three broad categories based on the character of the resource forming the feature: 1) extensive, 2) integrity, and 3) finite. These categories reflect different conservation needs and vulnerability to threat or change, and so can be related more easily to decisions around promoting (protecting or restoring) naturally functioning habitat mosaics as outlined in this report.

- **Extensive** sites contain geological features that are relatively extensive beneath the surface. The basic principle is that removal of material does not significantly deplete the resource, as new material of the same type is freshly exposed as material is removed e.g. exposures in a coastal cliff. The main conservation aim is to achieve and maintain an acceptable level of exposure of the interest features.
- **Integrity** sites are all geomorphological sites, and can be static relict features such as an esker (glacial sand or gravel ridge), or dynamic features such as a braided river that are still being formed by active geomorphological processes. Holistic management is the key to conservation of integrity sites and in the case of active geomorphological features it is

also important that natural processes are allowed to operate and have the space in which to do so.

- **Finite** sites, such as restricted mineralization or a fossil bed of limited extent, contain geological features that are limited in extent, so that removal of material may damage or destroy the resource. The basic conservation principle is to permit responsible scientific and educational usage of the resource while conserving it in the long-term.

Further subdivision of the above three categories, based on the character of the site in which the feature occurs (e.g. coastal cliff, disused quarry, road cutting, upland crag etc.) generates a more refined classification of sites, demonstrating similar conservation needs, susceptibility to threat, and management requirements.

Many geological sites are **extensive** sites and their conservation depends on maintaining an accessible exposure of the feature of interest, ensuring that exposures are not obscured by development, engineering schemes, infill or vegetation encroachment. Providing that sufficient exposure of the notified interest can be maintained, these sites usually offer sufficient flexibility to accommodate decision-making that promotes natural ecosystem function based on natural abiotic processes, and significant conflicts between biodiversity and geodiversity objectives are likely to be rare. Conflicts are more likely to occur where a geological site is small and there is limited flexibility as to where the exposure can be located.

Most **integrity** sites are geomorphological sites that either require retention of landforms in static sites or maintenance of active processes in dynamic geomorphological sites where features are still being formed. Those sites requiring active natural processes are likely to be highly compatible with decisions to promote natural ecosystem function, and may add weight to biodiversity arguments to retain natural processes when they are under threat (e.g. coastal and river engineering schemes). In contrast, those sites requiring the maintenance of geomorphological features (such as a limestone pavement or drumlin field) in a fixed state, may provide more of a challenge in promoting naturally functioning habitat mosaics, depending on how natural processes would affect such features if allowed to proceed.

Finite sites need very careful management to ensure that any loss of resource is strictly controlled. These sites are relatively few in number but probably offer the least ‘wriggle-room’ when they would be affected by restoration of natural processes.

The existence of synergies and conflicts relating to promoting natural processes at individual locations is very site-specific. In some cases, due to the local topography and the position of geological and geomorphological features of any of the three types described above, there will be little of no conflict of interest in restoring natural hydrological or sedimentological regimes. There may even be associated enhancement to some geological exposures or active geomorphological processes. In other cases, their location may provide difficulties in achieving large-scale naturalisation of ecosystem function.

Although geological and geomorphological features and habitats and species are identified and notified as SSSIs using quite different criteria, many SSSIs include features notified for both their geodiversity and biodiversity features. In the vast majority of cases this poses no obstacles to site management, and in many cases (such as coastal cliffs) the requirement of natural ongoing coastal processes meets the needs of all interests. However, in rare cases, the promotion of natural processes and natural ecosystem function may result in change in local management perspectives that could not have been foreseen at the time of notification, and which could create potential conflict of interest that was not evident before.

Even in such situations, in the majority of cases suitable local compromise between biodiversity and geodiversity interest should be possible. In some particularly difficult cases, in order to resolve major conflict of interest on a site, it may be possible to seek and notify equivalent geodiversity interest elsewhere where it exists and where it is scientifically justifiable, or to prioritise other sites with high potential for restoring natural ecosystem function. In other cases, the importance or needs of the geodiversity or biodiversity features in question may be so critical that this is not possible and a difficult decision to choose one over another may need to be made.

5.4 Landscape character and cultural heritage

Natural landscape characteristics (soils, underlying geology and hydrological pathways), combined with the climate received by the landscape, are fundamental determinants of the natural spatial pattern of habitats and associated species. Human activities such as drainage, engineering, grazing, tillage, felling and cutting (which may or may not have cultural significance) alter these patterns, with the magnitude of change generally increasing as cultural factors have intensified over time.

Landscape characterisation is the systematic approach used to objectively assess and describe how one landscape differs from another and the key characteristics and features that give rise to those differences between one landscape and another. Very often the natural landform and underlying geology and soils are significant factors in creating and sustaining the landscape features that make up the pattern of the landscape. Cultural heritage includes evidence of man's influence over time in shaping the landscape including land management practices, settlement patterns and other structures and artefacts.

The underlying synergies between natural factors and historical (low intensity) cultural influences often provide a sound basis for finding collaborative, integrated solutions to enhancing wildlife habitat, alongside landscape and cultural benefits. Conflicts may arise when the restoration of more naturally functioning habitat mosaics would generate significant change in a landscape which is designated or valued by society for cultural or other reasons. Such restoration may involve a shift in the nature of vegetation controls towards a more or less open landscape (more or less scrub and trees) or towards a less controlled landscape (e.g. less control of water levels and flows).

A local landscape character assessment provides evidence of whether any proposal will fit within the context of the existing landscape character and vegetation structure, and how it relates to the historical evolution of the landscape. Where such evidence supports a case for combined biodiversity and landscape restoration, it provides a good basis for consultation by tapping into the collective memory and perceptions of local stakeholders who may then support the proposals.

Restoration of naturally functioning habitat mosaics is challenging in locations where built heritage is present. In the freshwater environment this may take the form of water mills and associated weirs, leats and ponds alongside rivers, or artificially landscaped ponds formed in parkland by the damming of streams and rivers. Such features may be associated with populations of priority species that have benefited from the modifications, for instance, white-clawed crayfish might inhabit a pond of heritage value that was created from the impoundment of a stream. There may be options for retaining built features but restoring natural function around them, for instance by reforming a stream channel around a structure to allow natural geomorphological processes and the free movement of species. Weirs can be circumvented whilst left in place, and small residual flows can be maintained along mill leats (for instance by solar-powered pumps). In all instances the biodiversity benefits of restoring natural ecosystem function need to be clearly articulated, and the likely effect of any changes in the population size and distribution of priority species should be considered. In many cases, species of concern will be provided with restored natural habitat niches as a result of restoration.

Local decisions will be heavily influenced by the biodiversity, landscape and built heritage importance of any given site or area and the scale of effect of restoration on each. In some cases, where no special biodiversity designations apply and where there are landscape or built heritage notifications, if no suitable compromises are available then protection of landscape or built heritage is likely to take precedence. In cases involving areas with special wildlife designations, where restoration of natural function is agreed as an integrated biodiversity solution, greater weight would need to be given to such restoration.

5.5 Flood risk management

There are clear synergies between restoring more natural hydrological function to semi-natural habitats and flood risk management objectives based on Natural Flood Management (NFM). However, care needs to be taken to ensure these synergies are realised wherever possible. There is a risk of NFM measures leaning towards engineered solutions for increasing catchment water retention, slowing flood propagation in the river network and venting flood peaks onto the floodplain.

An example of the tension is the engineered and effectively permanent wooden weirs currently envisaged for installation in headwater streams as a NFM solution. These provide no biodiversity benefit and are potentially harmful to natural ecosystem function. A natural function approach involves restoring naturally functioning valleyhead mire and stream systems, with plentiful riparian trees providing woody material and leaf litter for natural, impermanent and partially effective ('leaky') debris dams, thereby restoring characteristic foodwebs (Mainstone *et al*. 2016, CaBA In Prep).

Measures grounded in the restoration of natural ecosystem function will ensure synergies between integrated biodiversity objectives and natural flood management objectives. This is as true at the downstream end of catchments (where the selective restoration of natural fluvial and coastal flooding regimes is the largest issue) as it is at the upstream end (where natural water retention and flood propagation are the largest issues).

5.6 Water resource management

Naturally functioning habitat mosaics help to restore catchment water retention, including infiltration to groundwaters, and hence help to maintain water availability through dry periods for both downstream water-related habitats and for water supply (Mainstone *et al*. 2016). They also help to improve water quality for water supply, including levels of nitrate, phosphorus, humics and colour and fine sediment. Hydrological restoration of blanket bog, valleyhead mire and stream complexes, and wet heath and bog mosaics will all contribute to catchment water retention. The *quid pro quo* is that the water requirements of these naturally functioning systems need adequate consideration in water resource planning.

5.7 Sustainable farming and woodland management

The concept of natural ecosystem function outlined in this report is inevitably based on semi-natural habitats. In this context there are major constraints on the improvements that can be made on intensively managed farms and forestry plantations (which occupy by far the greater part of our land area) unless there is a significant change in the business model applied to the land. In such areas there should be opportunities for small-scale land-sparing where some natural function can be restored, even if only to aid biological connectivity to larger and more naturally functioning parcels of semi-natural habitat. Parts of a farm that are marginal for commercial return, of low agricultural capability and perhaps agriculturally improved in the post-World War II drive for increased food production, is often the best land to consider for such land-sparing.

Natural ecosystem function is a concept most easily applied to more extensive farming and broadleaved woodland management systems where biodiversity is a more fundamental objective and semi-natural habitats are more prevalent. Land under this form of management may be owned by the state, NGOs or private landowners with a strong wildlife focus. Commercial products from such land are intimately associated with wildlife benefits and attract a premium price as a result, and additional incentives for wildlife-friendly management are provided by state-funded incentives. These conditions provide the basis for synergies with natural ecosystem function, although what can practically be achieved comes down to site-specific circumstances.

The concepts of land-sparing and land-sharing, terms used in spatial conservation planning, have multiple spatial scales that in some ways mirror the spatial organisation of habitats and ecosystems. At the level of a whole farm or forestry block, land might be perceived as being shared but in reality the land is apportioned between spared land (hedgerows, spinneys, wildflower-sown arable field margins, broadleaved buffer strips and rides) and land that is not shared (intensively managed pasture and arable). Alternatively, the whole farm may be shared in its entirety through extensive management providing lower commercial returns, or may be essentially completely spared by having no requirement for a commercial return and being run for wildlife by other financial means. In broad terms, the smaller the spatial scale of land-sparing, the greater the likelihood of emphasis on single species, few-species assemblages or individual habitat types, and the lower the scope for providing naturally functioning habitat mosaics.

In extensively managed areas of land supported by environmental grants, fixed management prescriptions can be a major constraint to the promotion of natural ecosystem function. The need to restore underlying processes and dynamism, and the resulting small-scale habitat heterogeneity with vegetation types that are difficult to characterise, mean that appropriate management prescriptions are difficult to define. In the future there are possibilities for approaches to awarding grants based on payments for outcomes, which offer considerable potential for supporting the restoration of more natural ecosystem function. The pilot programme on the Burren in the Republic of Ireland provides a useful demonstration of the utility of the approach (Dunford 2016), although the range of biodiversity outcomes specified has so far been narrow and would need considerable expansion to encapsulate naturally functioning habitat mosaics.

6 Principles for promoting more integrated biodiversity objectives

A set of integration principles have been drawn out of specialist discussions in this project, drawing on the context outlined in previous sections (Box 6.1). They have been divided up into ecological and practical principles, to help distinguish between: 1) how we should go about shaping our vision for biodiversity, and 2) what we can reasonably achieve in any one given location.

These principles build on our understanding of ecological relationships, using the concept of a spatial habitat template shaped by natural processes as a critical reference point in local evaluation and decision-making. Ecological relationships and the natural habitat template have to be understood at a range of spatial scales in order to ensure that all of our biodiversity objectives are adequately catered for.

The natural habitat template provides one lens through which a local landscape can be evaluated, looking from large-scale down to small-scale. The individual requirements of habitat types and species provide other lenses, looking from small-scale up to large-scale. Upscaling our evaluation to larger spatial and ecological scales provides much needed flexibility about how we cater for individual species and habitat types, as long as we retain our ecological understanding at smaller spatial scales. This ecological rationale is broadly captured in Figure 6.1.

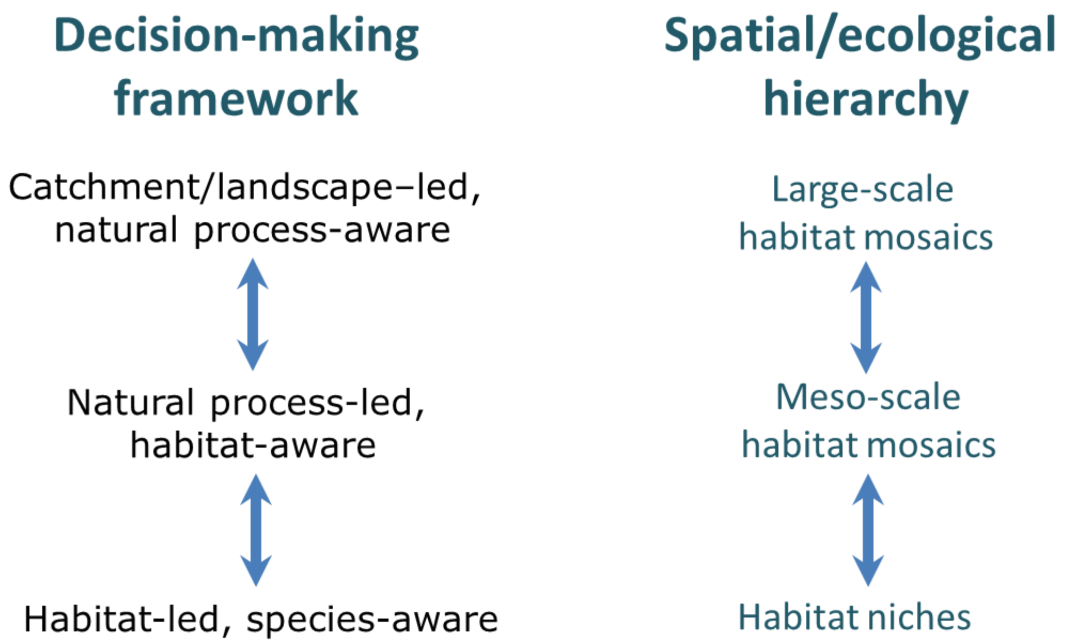


Figure 6.1 Ecological rationale for more integrated biodiversity decision-making.

Box 6.1 Principles for integrating biodiversity objectives.

Over-arching ambition

Promote natural ecosystem function where practical and desirable, to enable more integrated biodiversity conservation within naturally functioning habitat mosaics

a) Ecological principles

1. Consider larger spatial and ecological scales, whilst ensuring an understanding of small-scale ecological detail in evaluation and management decision-making – habitats form natural dynamic mosaics in the landscape which we need to recognise and conserve.
2. Understand how abiotic processes (particularly hydrology) would function naturally in the landscape in the absence of human modifications, according to climate (including climate change), topography and geology, and use this as a starting point for biodiversity planning.
3. Understand how ecological relationships (between habitats, between habitats and species, and between species) would operate in the landscape under natural abiotic processes, and use this as a spatial template for planning semi-natural habitat mosaics.
4. As part of understanding ecological relationships, consider how biotic processes (particularly herbivory) would function naturally, and use this to help refine the spatial template.
5. Treat all defined habitat 'types' as habitat mosaics in their own right, which are critical to the full complement of characteristic species. These mosaics have natural patterns governed by the landscape which we need to recognise and seek to conserve.
6. Understand what individual habitat types and species need, but be as flexible as possible in how those needs are delivered within landscapes.
7. Think about how naturally functioning habitats can deliver the requirements of individual species, however those requirements are currently met.
8. Recognise that the balance of habitat types within habitat mosaics, and species within assemblages, will change as a result of restoring elements of natural function – focus on the integrated biodiversity benefits across all habitats and species.
9. Understand the implications of restoring natural ecosystem function for the existing pattern of habitats and species in the landscape. Consider the loss and creation of niches as well as colonisation sources, pathways and rates.

b) Practical principles

1. Recognise practical constraints to restoring natural ecosystem function but take a long-term view (encompassing climate change) to ensure ambitions are not restricted by short-term considerations.
2. Prioritise restoration of natural function where practical constraints are lowest and biodiversity benefits are greatest – some types of landscape provide more inherent opportunities, but there are generally opportunities in some places within all landscapes.
3. Be explicit and transparent about considering the effects of any restoration plans on existing biodiversity, aiming to provide niches for key species in restored habitat mosaics in places where they are characteristic of the natural landscape.
4. Plan interventions where needed to safeguard critical populations and address any significant colonisation difficulties to new habitat niches, factoring in climate change implications.
5. Only use classifications where they are appropriate and don't treat them as fixed ecological entities – they can be useful in describing habitat and assemblage variation and in the development of restoration visions, but in practical conservation management can lead to neglect of natural dynamism, habitat transitions and fine-scale habitat mosaics.
6. Harmonise the use of key biodiversity mechanisms (priority habitats/species and protected sites) in ways that reinforce each other and provide ecosystem services that are compatible with natural ecosystem function.
7. Seek synergies with other objectives, integrating wider benefits of more naturally functioning ecosystems whilst searching for innovative solutions to conflicts.

Conflicts between habitat objectives can be lessened by greater recognition that the boundaries between habitat types are artificial constructs, and that typologies and classifications are only useful when their application serves a practical purpose. Classifications designed to describe ecological and biodiversity variation have inherent artificial boundary effects. These effects are acceptable when the classifications are used for their intended descriptive purpose (as long as the effects are acknowledged and understood), but become more problematic if the classifications are subsequently used to drive local management decision-making. Transitional habitats (ecotones) and fine-scale habitat mosaics can be neglected and the importance of dynamic change can be forgotten. A key issue in more integrated decision-making is therefore conditioning the use of classifications to avoid biodiversity objectives coming into conflict.

Allied to this, the existing content of priority habitat inventories may hinder attempts to restore natural function unless they are viewed through an appropriate prism. There will be cases where a geographical area is assigned as an example of one habitat type when under natural processes it would actually be perceived as a degraded example of a different habitat type. For instance, an example of rush pasture on drained peat would actually be a fen or bog if natural hydrology were restored. There needs to be recognition that perceptions of priority habitats may require altering to facilitate the restoration of naturally functioning habitat mosaics. The two-dimensional nature of the 'single habitat layer' provides a simplistic portrayal of priority habitats that can exacerbate the boundary effects created by classification – it needs to be interpreted carefully to avoid constraining aspirations for more naturally functioning habitat mosaics and attempts to generate more integrated biodiversity objectives.

It is important to recognise that the status quo may not be sustainable in the medium and long-term because of climate change and the associated rises in changes in hydrology and sea level rise. In some places, current habitats and species assemblages will not continue to be viable for a range of reasons including more frequent droughts, heavier rainfall leading to more 'flashy' hydrology, northwards shifts in species distributions and physical loss of coastal habitats. Restoration of natural processes is a major climate change adaptation measure (Natural England/RSPB 2014) and is central to restoring ecological resilience. It allows natural adjustment to new conditions, for example the development of new habitats, roll-back of coastal habitats inland and the colonisation of species whose climate space is changing. This contributes to resilience and can help the adjustment to inevitable change.

Restoration of more natural function can fall down because of a lack of knowledge of the ability of individual rare and vulnerable species to withstand the disturbance of restoration and to colonise new niches in more naturally functioning habitat mosaics post-restoration. This leads to understandable risk aversion in decision-making, and ultimately measures that maintain the *status quo*. This situation can be exacerbated by climate change predictions, which may suggest increased vulnerability due to contraction of climate space. These problems can be countered by greater understanding of the ecology and behaviour of such species and the likely effects of restoration and climate change on habitat provision, as well by seeking to target restoration in those areas which are not already 'special'.

In some cases, predicted shifts in the climate space of a rare species may lead to consideration of modifying natural processes to maintain the species in its current location. Whilst it is legitimate to maintain a species *in situ* for as long as it is possible in the face of climate change, the use of measures that work against natural function need to have a strong justification. Many of the natural function approaches discussed here will increase the potential to maintain species *in situ* (Oliver and Morecroft, 2015) or restore lost naturally functioning habitat in the vicinity to which they can migrate: population resilience may be enhanced by restoration of natural abiotic process (for example by reducing abstraction from water courses), increasing site size, restoring natural connectivity and restoring naturally functioning habitat mosaics that provide local small-scale (micro-climate) refugia where species can persist (Suggitt *et al.*, 2014).

Artificial site management approaches to climate change include augmenting water supply to maintain water availability at historical levels in the face of changing weather patterns and resulting hydrological regimes. Such approaches may be considered to be the only possible options at sites that are already highly modified (perhaps already having artificial water management) with no apparent prospect of naturalisation. The effects on the levels of natural function of off-site areas need to be considered, including the future potential to restore natural function to adjacent areas which would have benefits to a range of local habitats and species including (potentially) those at risk from climate change. Assisting species to move to more naturally functioning sites (either existing or restored) in the locality or region, where the probability of survival in a changing climate is higher, is arguably more compatible with natural function than such artificial approaches (although it carries its own risks).

Looking beyond ecological considerations, a major reason why we can encounter conflicting biodiversity objectives at a local level is different levels of aspiration for, or consideration of, the extent to which we can restore natural function in any given situation. Principles for integrated biodiversity decision-making therefore need to be grounded not only in ecological considerations but also include practical consideration of socioeconomic constraints and opportunities. Transparency in evaluating options, and in considering both the biodiversity and socioeconomic consequences, is paramount in reaching consensus on the right level of ambition in any given circumstance.

Time horizons are critical to achieving the best outcomes. Longer time horizons create far greater scope for more integrated biodiversity objectives that can be embraced by local stakeholders. They create space for consensus-building, as well as for the cultural shifts in mindset that are needed for such consensus.

7 Applying principles to local circumstances

The case studies provided in this section attempt to illustrate how a more integrated approach to biodiversity objectives based on natural ecosystem function can be considered in different types of landscape and situation. They are existing, on-going examples of work and therefore have not been subjected to structured consideration of the ecological and practical principles outlined in Section 6. However, a footnote is provided in each case study indicating which integration principles are felt to be best demonstrated.

The integration principles outlined in Section 6 can be applied to any local circumstance and to any spatial scale, but some situations provide greater opportunities than others. Greatest biodiversity benefits are possible where existing biodiversity interest is low but there is proximity to biodiversity hotspots from which colonisation of restored habitat can occur. Practical opportunities will only exist where socio-economic factors allow, and are more likely to be realised where socio-economic benefits accrue from restoring natural function. Current land use and the location of infrastructure (roads, railways, water supply networks etc.) may make such restoration impossible. The pattern of intensification of land use and the spatial scale of the natural processes that need to be restored influence the scale of opportunities and the level of ambition that is possible.

Given the fundamental influence of water in the landscape, and the large-scale land drainage and flood defence works that have occurred in England, it is inevitable that consideration of water is central to identifying the best opportunities for restoring naturally functioning habitat mosaics for integrated biodiversity objectives. Targeted at natural hydrological pathways in the landscape, restoration measures not only generate the most comprehensive naturally functioning habitat mosaics, but also deliver a range of socioeconomic benefits associated with water (diffuse pollution control, catchment water storage etc.), improving natural capital and ecosystem services (water quality and supply, flood risk management). Identifying and generating vegetation management regimes that mimic natural controls, to provide an appropriate mix of open, scrubbed and wooded habitats, disturbed and undisturbed soils, is a subsequent consideration but equally fundamental to integrated biodiversity outcomes. In most cases, this vegetation balance will involve increased cover of scrub and trees, which will not only restore more natural and biodiverse habitat mosaics but also improve a range of water-related ecosystem services (Nisbet *et al*. 2011). Restoration of natural nutrient supply and status, and the control of non-native species, are further layers of decision-making that ensure we get the desired response from native plant communities, and through this native fauna.

Small headwater catchments are relatively self-contained in terms of natural processes (particularly in terms of hydrology), so their restoration has limited land use and management consequences. Restoration of valleyhead mire, stream, scrub, trees and grassland mosaics can be a relatively small-scale project addressing multiple habitat and species objectives. Some headwater catchments (both upland and lowland) have escaped the heavy modifications that have occurred across much of the English landscape, and serve as illustrations of the biodiversity value of more naturally functioning habitat mosaics (e.g. the ancient woodlands of the High Weald and the mosaics of springs, flushes, wooded streams and grasslands of the South Cotswolds.

Headwater catchments occur in both upland and lowland landscapes and so provide opportunities across England. The positive effects of hydrological, physical and vegetation restoration (elements that are intimately linked) are not only felt in the headwater catchments themselves but also in all downstream areas (improved water quality, improved water storage and provision, reduced flood flows). All this makes them good places to focus efforts to restore natural ecosystem function. Individually small restoration schemes in headwater catchments can be planned in combination at larger spatial scales, and implemented in a modular and sequenced way according to the availability of resources (see Boxes 7.1 and 7.2). Basin wetlands, with small surface water catchments sitting in larger hydrological units, provide similar opportunities to headwater catchments (Box 7.3). In the moorland fringe, in addition to restoration of ghylls and associated mires, the restoration of more natural grazing regimes around the moorland fringe can create a more diverse mix of open, scrub, trees and woodland habitat (Box 7.4).

Large and heavily developed river and coastal floodplains are amongst the most difficult areas in which to restore natural function. However, even in these landscapes there are opportunities for limited restoration of some natural processes to the benefit of characteristic habitat mosaics and the species they support. In floodplain margins, for instance, valleyside spring lines and associated flushes and mires can be restored through drain-blocking, with benefits to a wide range of plant and invertebrate species as well as wading birds such as snipe and redshank (Box 7.5). Naturally functioning habitat mosaics can be extended up the valley sides to incorporate drier grassland, scrub, trees and woodland habitats. Such measures do not interfere with existing intensive uses of the floodplain.

In some cases, large-scale change is being increasingly considered on river and coastal floodplains due to the over-riding difficulties of defending land from flooding in the face of climate change. In these instances restoration of natural ecosystem function can be contemplated on a larger scale (Box 7.6). In some instances, typically involving relatively narrow floodplains with low intensity grazing, the socioeconomic case for maintaining historical flood defences is not sufficiently strong and the case for restoring naturally functioning habitat mosaics is compelling. Such restoration creates more comprehensive biodiversity benefits if undertaken in conjunction with upstream naturalisation measures (Box 7.7).

Prioritising restoration measures along these lines risks ignoring the importance of more agriculturally developed land that has provided (and still provides) refuge for species whose natural habitats have been eliminated from the landscape. We need to ensure that such habitats continue to fulfil their role as a refuge for displaced species, whilst at the same time ensuring that they do not unduly obstruct the restoration of more naturally functioning habitat mosaics where this is practicable. In larger landscapes it is possible to zonate restoration areas whilst safeguarding some artificial refugia; for instance, part of a grazing marsh system could be restored to natural hydrological function by in-filling ditches, whilst areas of adjacent grazing marsh could be retained to maintain species populations and provide colonists to restored areas. On intensively farmed valleysides, individual hydrological pathways might be naturalised, with appropriate vegetation controls to generate a mosaic of wet and dry, open, scrubbed and wooded vegetation, whilst the rest of the landscape remains in intensive agriculture.

Increasing the extent of artificial refugia may be appropriate in areas where there is no potential for restoring natural function in the locality. However, such potential needs to be considered in an integrated way and at sufficient scale. For instance, there is no value in encouraging the sowing of wild flowers in arable field margins on a piece of land that would create far greater and more integrated biodiversity benefits if it formed part of a scheme to restore a naturally functioning habitat mosaic around a basin fen. Equally, a judgement may be needed about the relative priorities of extending artificial habitats in one location and restoring naturally functioning habitat mosaics at a different location some distance away.

Box 7.1 Integrated biodiversity objectives in the New Forest – Jenny Thomas, Lead Adviser, Natural England.

The New Forest is one of the largest terrestrial Sites of Special Scientific Interest (SSSI) in the UK and is internationally recognised as a Special Area for Conservation (SAC), Special Protection Area (SPA) and Ramsar wetland. It supports a wealth of wildlife including a large number of very scarce plants, animals, invertebrates, birds and fungi.

Despite extensive drainage and stream modification, the site retains a highly important mosaic of wetland habitats, including riverine woodland, bog woodland, valley mires, wet heath, wet grasslands, flushes, runnels, streams and pools. This mosaic provides a haven for rare species such as southern damselfly (*Coenagrion mercuriale*) and Hampshire purslane (*Ludwigia palustris*), as well as previously much more widespread species such as large marsh grasshopper (*Stethophyma grossum*), curlew (*Numenius arquata*) and snipe (*Gallinago gallinago*). The wetland mosaic merges into drier habitats (scrub, dry heath and woodland) away from surface hydrological pathways, on the watersheds between stream catchments, which completes the full habitat mosaic of the Forest.

The wetland components of the habitat mosaic are being restored through blocking up the drains that were cut through the mires, and restoring the bed levels, channel dimensions and original meanders of the streams that were straightened, deepened and widened to facilitate the drainage. This work is restoring natural function on a landscape scale, restoring niches for all of the characteristic wetland flora and fauna of the Forest in balance with dryland habitats and their species complement.

Restoration work is sequenced around the Forest, within different hydrological compartments (small headwater catchments). Early restoration schemes provide a tangible demonstration of success for later schemes to follow and refine. The Forest provides a clear example of the benefit of operating at large spatial scales, and is almost unique in lowland England in being a large-scale ‘site’. However, it also shows how naturally functioning habitat mosaics can be restored in individual headwater catchments, even where they are located in more developed landscapes.

Grazing of the common land provides a relatively natural spatial pattern of vegetation control more suited to conserving natural habitat transitions and small-scale habitat mosaics. This creates areas of bare ground for a range of specialist plants and invertebrates, such as pillwort (*Pillularia globulifera*) and medicinal leech (*Hirudo medicinales)* 'Lawns' have been created by this historical grazing regime, which support specialist plant species. The freedom to roam across a large area allows animals to avoid very wet habitats, generating a natural concentration of grazing activity on drier ground and at open water margins. Care is still required to ensure that that the overall level of grazing is appropriate to avoid excessive disturbance and encourage sufficient vegetation structure and natural regeneration of woodland and scrub. Random variation in the level of management activity around the Forest provides scope for natural regeneration and new areas of broadleaved trees are appearing.

Restoring wet heath and mire through drain-blocking inevitably reduces the area of dry heath to pre-drainage levels. Plant species such as heathers, gorse and bracken, and associated fauna such as the silver-studded blue butterfly, ground-nesting birds, and reptiles such as adder, will have benefited from the drainage, However, the land area directly influenced by natural hydrological pathways in the Forest is relatively small and there is a large amount of dry heath away from these pathways, so the overall effect on dry heathland and its species is relatively minor. In addition, much of the drained land has been covered in forestry plantation and so has not been functioning as heathland. Some ditches that have been blocked may have been perceived as degraded stream habitat in need of restoration, but these only existed because of historical drainage operations that eliminated the natural habitat mosaic. Some species of small pools, such as Hampshire purslane and pillwort, lose habitat that has been created by modifications to hydrological pathways (ditches with small amounts of water in them, and water trapped by floodbanks). Restoring natural small-scale variations in topography in the restored mires and wet heath is critical to these species, and the recorded increases in these species within the Forest demonstrate they are well catered for.

The ecological and biodiversity changes are a rebalancing of natural ecological relationships, to allow the full species complement of the locality to be conserved. The scale of the Forest, its natural environmental diversity and the long continuity of extensive management (which has preserved its species complement and a rich seedbank) means that such readjustments occur rapidly.

Footnote: This work provides a good demonstration of ecological principles 1, 2, 3, 6, 7, 8 and 9 and of practical principles 1 and 5. Work to reconcile biodiversity restoration strategy within the Forest with designated geodiversity interest is on-going (relates to practical principle 7).

Box 7.2 Developing an integrated restoration strategy in the Forest of Dean – Alisa Swanson, Lead Advisor, Natural England.

The Forest of Dean has a long history of human use for wood and charcoal, as a royal hunting forest since Saxon times, for iron ore and coal mining from the industrial revolution until recent times, and latterly for large-scale commercial forestry. It was historically highly biodiverse, consisting of a patchwork of high quality heaths, mires, streams, grasslands and woodland. The intensity of historical land use and management has had major effects on habitats, although it retains interest for a range of species including woodland birds, bats, butterflies, fungi and lichens. The Forest includes a number of small SSSIs notified for various species interests, some of which form part of a composite SAC for bats (notably greater and lesser horseshoe bats - *Rhinolophus ferrumequinum* and *Rhinolophus hipposideros* respectively).

Whilst the landscape has a long-standing historical legacy of hydrological modifications and pollution related to mining and associated industry, intensive forestry management is now the dominant land use and leaves the most visible impact on the habitats of the forest. In recent decades there have been major drainage programmes across much of the Forest, and in the Woorgreens area this has been associated with extensive land-forming operations following the cessation of open cast mining. The headwater catchments of the Forest streams have been heavily desiccated, with major losses of flush, mire and wet grassland vegetation. Some remaining semi-natural areas have changed from wet heath or mire to relatively poor quality dry heath. Conifer planting has involved extensive loss of native broadleaved woodland and also open heath and grassland areas, creating fragmentation of remaining areas of semi-natural habitat. Despite all this, some of the middle reaches of the main streams of the Forest have recovered considerably through natural processes (sediment deposition and erosion and their interaction with tree root systems and fallen wood).

Degraded dry heath within drained areas

Drainage of headwater catchment with plantation beech

Natural geomorphological stream function further downstream

There is now considerable interest and enthusiasm for targeted restoration of natural ecosystem function within the Forest, as part of a broader strategy to reinvigorate the local economy through recreation, tourism and other activities. In particular, there is a greater appreciation of the ecological importance of natural hydrological processes and open habitats, as well as lost broadleaved woodland habitat. Restoration has to balance a range of interests including the primary need for a commercial return by the major landowner, Forest Enterprise. The wettest areas of the forest have received the greatest forestry drainage activity but have often still not performed well in forestry terms – these, together with adjacent areas of drier land (to provide complete the hydrological spectrum), are the most obvious locations to target for restoration.

A restoration strategy for the Forest is currently being developed. Biodiversity measures will need to include the targeted in-filling of drainage ditches and associated clearance of conifers. Once re-wetting has occurred, the natural hydrology of target areas can be reviewed and a clearer picture of natural vegetation patterns will emerge. The Forest has retained its low nutrient status soils and water, and the native seedbank should be relatively intact. There is therefore considerable potential for natural regeneration of both open and woodland/scrub vegetation according to natural hydrological gradients in the target restoration areas within the landscape. This will provide better scope for genetic diversity in the woodland and scrub that develops compared to active planting schemes, and hence greater resilience to disease.

Wild boar/domestic pig hybrids in the Forest of Dean

The strategy being developed for vegetation control, to generate a dynamic mosaic of open and closed habitats, is considering the role of wild boar (*Sus scrofa*) and European beaver (*Castor fiber*) as ecosystem engineers. Both are native species of habitat mosaics of woodland and open vegetation with marshy and open water areas, but both need to be subject to natural levels of population regulation to ensure their disturbance effects are ecologically beneficial and do not become extreme and damaging to biodiversity. A population of wild boar has been established in the Forest for some time and is expanding rapidly. This population is having an increasingly dramatic local disturbance impact and requires a coherent control strategy that mimics natural predatory pressure from the historical predators of wild boar in Britain (humans and the extinct grey wolf). A beaver reintroduction trial is in the early stages of consideration in part of the Forest. A local feasibility study for reintroducing the pine marten is also underway.

A restoration strategy for the Forest based on targeted increases in natural ecosystem function will require a flexible biodiversity perspective. Some areas of land that are currently degraded dry heath will be restored to wet heath or mire, and some areas that are currently woodland will need to be (at least partially) opened up. However, the resulting mosaic can contain all characteristic habitats operating according to their natural relationships, building on the remaining species interest and reducing fragmentation and increasing connectivity. These changes can be expected to benefit many native species, including the notified populations of greater and lesser horseshoe bats which rely on the habitat within the forest for foraging and roosting.

Exmoor ponies helping with heathland restoration in the Forest of Dean. Photo courtesy of Kevin Caster, GWT

The extensive damage to habitats within the Forest means that the risks of unintended biodiversity consequences from habitat restoration are greatly reduced, although they still need to be fully considered in restoration planning. Other restoration measures required include addressing the legacy of pollution and hydrological impacts from mining (as far as this is possible), which affect the natural flow regime and water quality of the stream system.

The development of this project shows the integrated biodiversity approach working: national habitats and species specialists are working closely with Area Team advisors and external partners, such as Forestry Commission and the Gloucestershire Wildlife Trust, to help pool resources and knowledge for the long term benefit of such a significant site.

Footnote: This work provides a good demonstration of ecological principles 1, 2, 3, 4, 6, 7 and 8, and of practical principles 1, 2, 6 and 7.

Box 7.3 Restoration of Quoisley Meres, Cheshire.

Quoisley Meres in south Cheshire are part of the wetland complex known as the Meres and Mosses of the West Midlands. This wetland area developed following the retreat of the glaciers from the last Ice Age. The glaciers left a very hummocky landscape in which ridges of sand, gravel and till created basins in which lakes subsequently developed. Some of these lakes became peatlands as the lakes were infilled with organic matter from fens and swamp woodlands.

Quoisley Meres sit within one of these basins, which drains to the west and at one time formed the head of a peat-filled valley (brown shading denotes area of deep peat) stretching for many miles to the north and east. The site is fed by a mixture of surface run-off and groundwater derived both from the shallow sand and gravel aquifer, which outflows in numerous springs and seepages on surrounding slopes, particularly to the south and east and possibly directly from below. They receive water from their relatively small catchment as surface run-off and groundwater issuing from the slopes above the basin.

From its likely natural state of a large area of standing water, swamp woodland and extensive seepage areas on surrounding slopes, progressive drainage of the basin and its surrounds had by the 1960s left the site as two distinct meres, with surrounding fen and a strip of wet woodland. Rushy pasture was found between and around the meres including the local rarity meadow thistle *Cirsium dissectum*. The groundwater outflows on surrounding slopes were drained by pipes and ditches.

In common with nearly all of the other meres in the area, drainage of the basin bottom was affected by deepening the outflow, drainage of the area immediately around the meres and digging of radial ditches through the peat body. The impacts of this included loss of area of open water, wet fen and swamp and shrinkage of peat and a concomitant increase in the area of drier ground that was more suitable for agricultural exploitation.

It was in this modified state that the site was designated as a site of special scientific interest in the 1960s, with features of interest identified as open water and rushy grassland. Over time, however, and in the absence of regular ditch maintenance, the artificially deepened outflow began to re-vegetate and slow the flow of water from the basin. This resulted in gradual re-wetting of the basin floor, with the two meres increasing in size and lesser pond-sedge and bottle sedge swamp spreading into areas regarded as ‘grassland’.

This created some interesting challenges for those involved in the SSSI as the rise in water levels was in effect destroying one of the ‘interest’ features of the site, namely the wet grassland. Initial thoughts were to re-instate regular ditch clearance to restore grassland. However, following survey of the developing wetland habitats and identifying the desirability of restoring a more natural hydrological regime it was decided that the outflow should be ‘formally’ and permanently restored to something more like its original state. Following a feasibility study, which considered options for blocking, and potential impacts on the site and neighbouring ground, around 20m of the outflow downstream of the mere mouth was infilled with material gathered from surrounding land.

Shortly after this work started, a survey of the snails of the West Midland Meres revealed that Quoisley Meres supported a very large population of Desmoulins whorl-snail, an uncommon species previously thought to be largely restricted to base-rich wetlands in the south and east of England and Anglesey. In addition to Quoisley, the snail was also found in significant numbers on some of the other more alkaline meres in the area. This is a species of permanently wet sedge fen, so it is likely that the relatively recent expansion of the sedge swamp following the development of wetter conditions at Quoisley has been to its benefit. Recent population estimates suggest that the site supports the largest population of the species in England.

While the work to date has sought to restore the meres to a near-natural status, the hydrological regime of the wider peatland and feeding slopes remains fairly modified. Some of this land lies outside the SSSI boundary, so restoration relies on the interest and good-will of the landowners. This land is of course critical to the restoration of the full range of wetland habitats, to providing adjacent terrestrial habitats in a full transition from open water to dry land, and to the ecological resilience of the whole system. In particular it provides opportunities for the restoration of peaty grassland habitats on areas of intermittent seepage that were lost from lower ground as the water levels in the meres rose. In an ideal world the full restoration would have been planned, with the migration of the grassland and species of drier habitats being facilitated as they were lost from inundated areas. This is the model that is now being followed on similar sites across the Midlands Meres and Mosses Ramsar site.

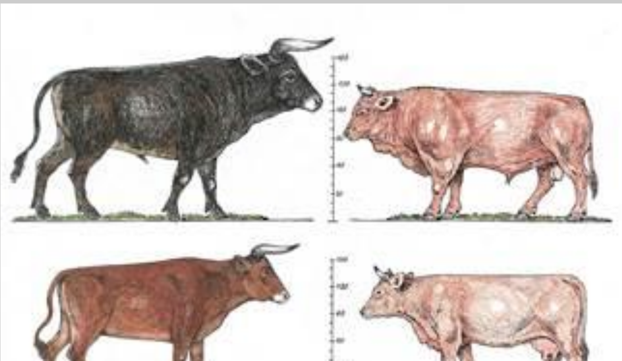
Footnote: This work provides a good demonstration of ecological principles 1, 2, 3, 6, 7, 8 and 9 and of practical principles 1 and 2.

Box 7.4 Restoration of more natural vegetation controls on Geltsdale Farm, North Pennines – Simon Stainer, Lead Adviser, Natural England

Geltsdale Farm comprises 2600km^2 of upland lying within the Geltsdale and Glendue Fells SSSI, and the North Pennine Moors SAC and SPA. It is in private ownership (The Weir Trust) and managed by a tenant farmer, with RSPB owning the sporting rights as part of their 'Geltsdale Reserve'. Geltsdale Farm is unusual in the North Pennines in that it has a significant stand of ancient wood-pasture dominated by open-grown scattered trees of alder, birch and hazel.

The blanket bog on the site was hydrologically restored in 2007 and active *Sphagnum* growth is now restoring the habitat mosaic. In 2009, an HLS agreement was established to improve the naturalness of vegetation controls across the farm. The flock of 1200 sheep was replaced with a herd of Luing cattle, which has grown to 92 breeding cows in 2017. To facilitate more natural grazing patterns, most of the moorland fences were removed, and the cows have 'free-roam' over the fell.

The Luing cow is an ecological proxy for the auroch, *Bos primigenius*, which was present in the British fossil record for 1.5 million years prior to its extinction in the 13th Century. All domestic cows are descendants from the original auroch, which roamed across a vast Eurasian landmass, and our wildlife and trees have co-evolved with it and other large animals which re-cycled nutrients and disturbed vegetation succession in the landscape.



Size comparison: auroch left: domestic cow (from Van Vuure)

Luing cows, Geltsdale

A key change on the site since 2009 has been the development of a structurally more complex vegetation mosaic. The cattle choose to graze some areas preferentially, and others not at all; they ignore the blanket bog for example, and rarely enter the steeper-sided ghylls. The more frequented areas are disturbed with dunging and small-scale poaching, which form an important part of the structural change. Natural regeneration of hawthorn and alder is occurring in limited areas - young trees are browsed by cows to some extent, but after struggling through a period of suppression they are still able to mature and expand. Over time, a complex mosaic will develop consisting of more naturally functioning grassland, mires, heath and bog, and an open patchwork of scrub with locally prolific regeneration. The wood-pasture will be regenerated and will expand on the lower fell, and a ragged fringe of scrubby vegetation will develop in a natural transition into moorland, extending up the ghylls to generate restored mire-stream transitions and naturally functioning stream habitat.


Alder regeneration along Old Water


Browsed hawthorn regeneration – plants generate more branches and spines

Black grouse is present in the North Pennines but in low numbers because of its preference for successional or mosaic habitats which provide a range of niches and foods – these conditions have been lost from the moorland fringe because of land management over a long period of time. The developing structural complexity of the vegetation on Geltsdale Farm is providing a broad and varied habitat for this species, as well as many others. There were 9 male black grouse (*Lyrurus tetrix*) present on the wider RSPB Geltsdale reserve in 2009 (RSPB counts). Since the sheep were replaced by cows, numbers of black grouse have been increasing with intermittent population declines. The recent population peaked at 59 male birds recorded in 2015, before declines in 2016 back to 27 males. In the 2016 crash year, 81% of the birds were recorded on Geltsdale Farm, and it is the leks at this site that are providing the bulk of the population expansion. The black grouse heralds the return of other species that are dependent on more natural upland habitat mosaics. For instance, the argent and sable moth *Hastata nigricans* was newly recorded in Geltsdale in 2015 - its food-plants include birch and willow, so an easy correlation can be made between the regenerating upland scrub and the presence of this species.


Black grouse Lyrurus tetrix


Argent and sable moth *Hastata nigricans*

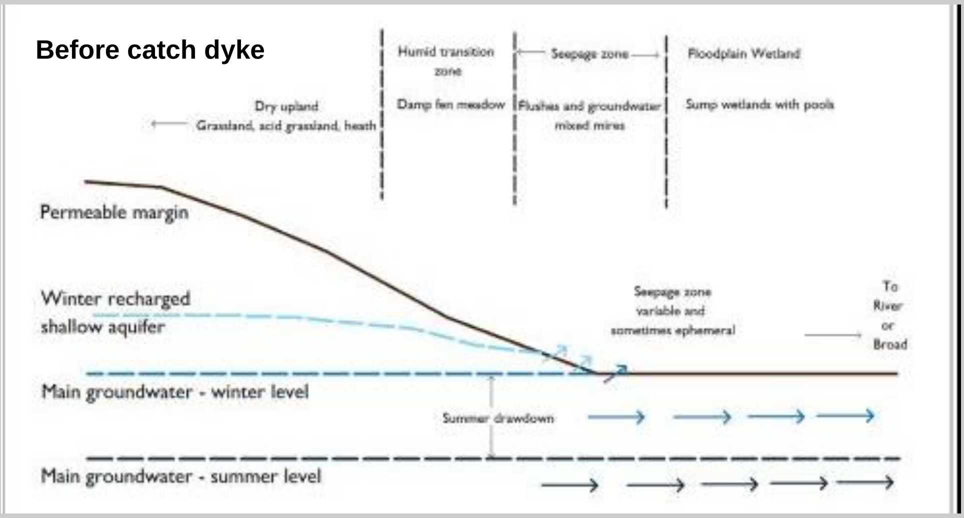
Footnote: This work provides a good demonstration of ecological principles 1, 2, 3, 4, 5, 6, 7, 8 and 9 and of practical principles 1 and 2 and 5.

Box 7.5 Restoration of a naturally functioning habitat mosaic around the floodplain/valleyside interface, Bure Valley, Norfolk (OHES, 2015; OHES 2016)

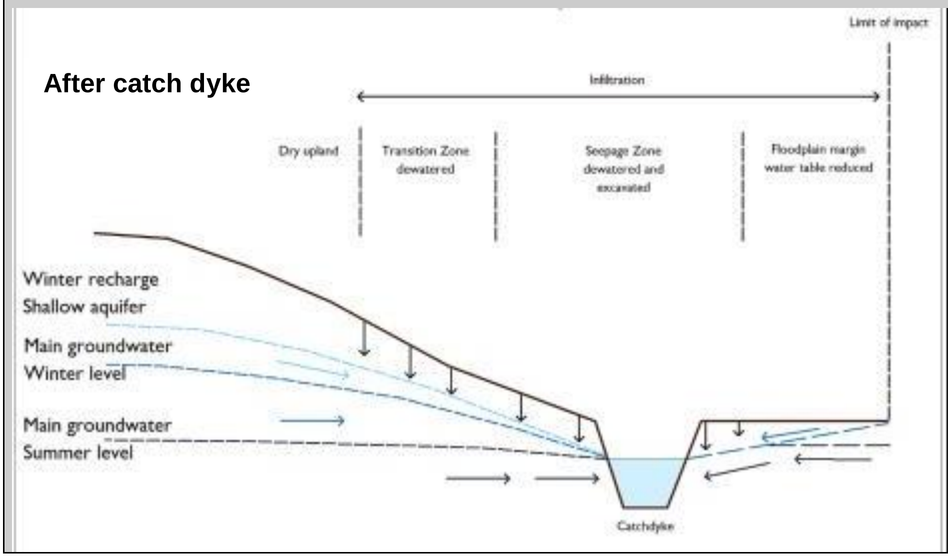
Floodplains in the English lowlands have been subject to drainage initiatives for hundreds of years, including attempts during Roman times to drain land for agricultural purposes. As populations have grown and technology has advanced, drainage of floodplains has become more comprehensive with the result that there is now little or no naturally functioning floodplain in the English lowlands. As a consequence, there has been enormous loss of wetland habitat and associated species.

The Broads, in Norfolk and Suffolk, retains some of the least modified floodplain, with large areas of floodplain fen and other wetland habitat surviving in the valleys of the Ant, Bure, Thurne, Waveney, and Yare rivers. Despite the survival of this very important wetland, these sites are far from unmodified, and are subject to various drainage pressures both within the wetlands themselves and in the wider landscape, including the effects of groundwater abstraction.

In the Broads, one of the more significant drainage impacts is that of catch drains or catch dykes. These are drains whose purpose is to both intercept run-off from the higher ground and drain the line of shallow groundwater input to the fringes of the valley bottom. Their intention is to improve drainage of the lower slope of the valleyside and of immediately adjacent floodplain land. They are usually dug along the break of slope between the flat floodplain and the rising ground, and are linked into the main regional drainage system.



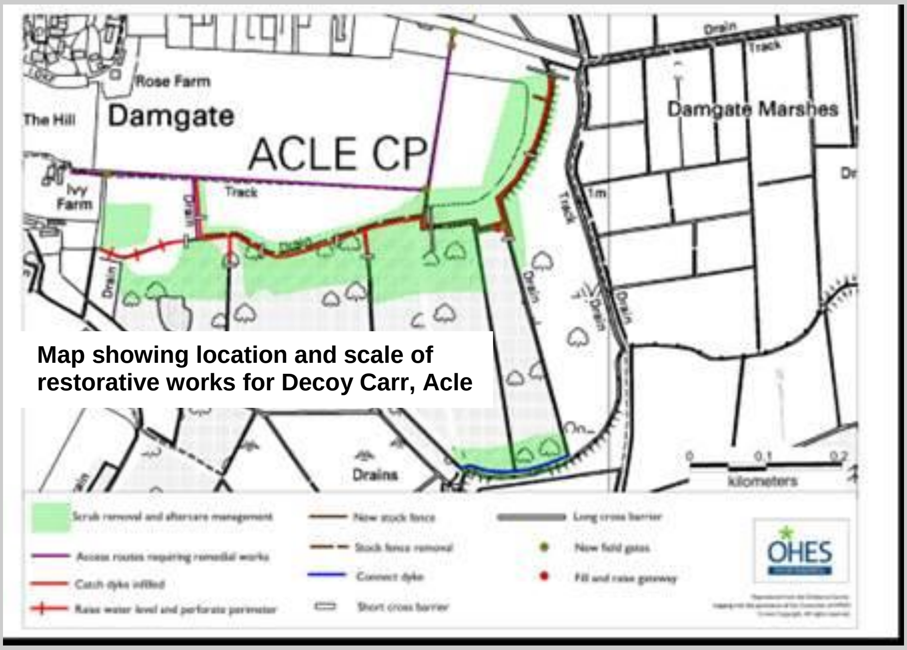
These before and after diagrams illustrate the pre and post- drainage arrangement of habitats on this 'valleyside- floodplain transition, and the impact of the catch dyke on the position of the water table. In an unmodified state there is a gradient of soil moisture from dry higher ground to lower ground, including areas of groundwater seepage and very wet conditions below these, including pools. Across the valleyside and immediate floodplain this provides a mosaic of dry, wet and waterlogged soil conditions capable of supporting a wide range of habitat types, including open, scrub and wooded vegetation The range of micro-habitats and species niches in this mosaic is very wide, After the catch dyke is dug, the water table drops, so groundwater seepage no longer occurs, the upslope areas are dewatered and the back of the floodplain is drier. The complexity of the habitat is greatly reduced, limiting the number of niches available for wetland species. In addition, the loss of groundwater feed to the surface changes the wetland water chemistry, often with the loss of low nutrient mineral enriched water that is so important for many species.



Natural England commissioned studies of catch drain impacts and opportunities for restoration in the Broads in 2014. Following this, several areas were identified as potential restoration sites, including Decoy Carr, Acle, in the Bure floodplain. This site was known in the 1950s as a very high quality, low-nutrient calcareous fen with records for species of very wet conditions and calcareous groundwater seepage, including the nationally rare slender cotton-grass *Eriophorum gracile,* and the rare mosses *Tomentypnum nitens and Cinclidium stygium*. Since then, however, several drainage initiatives – including deepening of catch dykes - have resulted in the loss of many of the species of this habitat, and the loss of the much of the groundwater seepage and general drying of the site. This has had a major impact on the natural diversity of the local habitat mosaic

Photograph showing the catch dyke from the valley side looking down over the fen below.

Detailed plans have now been drawn up to restore the full range of conditions by in-filling the catch dyke to reinstate the movement of groundwater from the edge of the valley into the floodplain. Included in this are assessments of likely impacts on surrounding land, and on the existing habitat, which still retains considerable wetland interest. A potential conflict is the presence of a rich ditch flora in parts of the catch drain, which would be destroyed by in-filling. While the aspiration is that suitable conditions for these species would be created on site by restoring natural hydrological processes and the subsequent development of pools, in the short-term these species will be conserved in a section of the drain that will not be in-filled, although piling will be inserted at both ends of this section to prevent loss of water.



Map showing location and scale of restorative works for Decoy Carr, Acle

Baseline survey has been done, with linked vegetation surveys and a network of water level monitoring stations installed. The impacts of the work will be closely followed and the results used to inform future restoration work. The applicability of this approach is potentially very wide both in the Broads and across the country as catch dykes are features of many floodplains, including protected sites. In some situations, catch dyke restoration may be achieved where more comprehensive floodplain restoration is not possible due to constraints on river channel naturalisation. Increased understanding of modifications to the whole hydrological environment in floodplains should be encouraged in order to identify such opportunities.

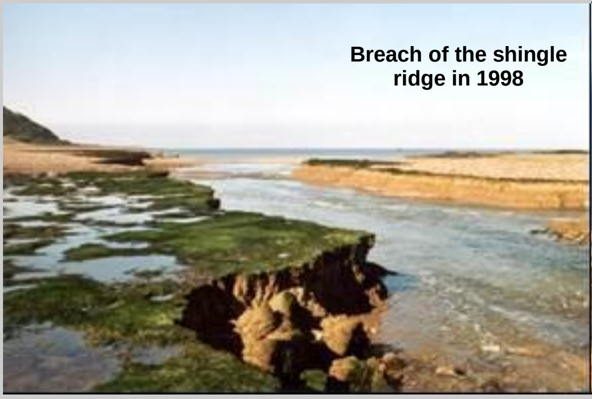
This work provides a good demonstration of ecological principles 2, 3, 6, 7, 8 and 9 and of practical principles 2, 3 and 4.

Box 7.6 Integrated biodiversity perspectives on restoring more naturally functioning coastlines: the case of Porlock Bay - Flemming Ulf-Hansen, Lead Adviser, Natural England

Porlock Bay lies to the north of Exmoor and contains a small coastal and river floodplain bounded by steep valley sides. The floodplain is fed by a number of small rivers that run off moorland slopes, either through steep wooded valleys or a farmed open vale. There is a natural shingle ridge running across the coastal strip, with associated vegetated shingle and saltmarsh.

The ridge has very little contemporary natural supply of material to sustain it, and the harbour at Porlock Weir and groynes along the coast may have further diminished supply. As a result the ridge has become thinner in recent decades. The land behind the ridge was historically developed into grazing marsh, which has over recent decades been subjected to saline inundation during storm surges and associated breaches of the shingle ridge. The coastal strip was designated SSSI in 1990 for its strandline vegetation, shingle, maritime grassland, saltmarsh, swamp and brackish water habitats.

As with many coastal locations in England, there has been freshwater-related biodiversity interest behind the shingle ridge that is being affected by the loss of resistance to saline inundation. This interest was associated with traditional farming of the hinterland, which is also being affected. The shingle ridge had been artificially managed in recent decades to restore and stabilise it to improve its flood defence capability, but this management proved to be increasingly difficult to sustain in the face of climate change and had possibly reduced ridge stability.



Breach of the shingle ridge in 1998

The situation forced a reappraisal of management, and in late October 1996 a storm surge forced by Hurricane Lili superimposed on the high tide caused massive over washing, demolishing the barrier crest and moving gravel onto the back barrier area. This major breach was not sealed by longshore sediment transport. Seawater inundating the marsh and emptying has eroded the breach so that tides can inundate the marsh regularly. The ridge and marsh is now being allowed to change naturally, and unusually the SSSI has been re-notified to recognise the active coastal geomorphological features as well as its vegetated shingle and saltmarsh, lose some freshwater interest features, and add some areas inland to allow for further changes in the pattern of shingle deposition and saltmarsh development.

The changes to a more natural system have resulted in restoration of naturally functioning saline habitat mosaics but so far there has been no restoration of freshwater components of the wider coastal habitat mosaic. The net effect of the changes have seen an increase from a few ha to over 40 ha of saltmarsh at the expense of freshwater grazing marsh habitat (12 ha improved grassland and 28ha mesotrophic grassland), 4ha of reedbed/swamp and lagoon. Most of the shingle ridge now has a natural form with vegetated shingle spreading on landward fans. Species losing habitat extent from these changes include some wetland birds. Overall wintering wildfowl numbers probably have fallen since the breach and the marsh is no longer suitable as a breeding site for shelduck because of regular inundation. The same is to some extent true of waders, since lapwing and redshank were sporadic breeders (no recent records). Loss of artificially created freshwater wetland interest behind the ridge was expected, but the restoration of the full saline transition zone in habitats, from fully saline to fully freshwater, is needed to allow freshwater-related species to shift to natural niches in the landscape (to the extent they can exist).

The small rivers draining into the central part of the floodplain coalesce into the Hawkcombe Stream. This watercourse follows a historically straightened course through a former alluvial fan. The stream is likely to have been embanked prior to the 19th century and the reclaimed land has since been used for agricultural purposes, The stream has been heavily modified as it flows through Porlock village and downstream the stream channel is ‘perched’ (elevated above the floodplain). Consideration is now being given to options for renaturalising the river in parallel with the natural change to the shingle ridge and marsh, which would help restore a full saline transition zone where it enters the marsh. This in turn could facilitate the restoration of small areas of freshwater fen, reedbed and wet grassland in the floodplain fringes – these are likely to be considerably more limited in extent than the artificially maintained freshwater wetland interest that existed before, but they would conform more closely to the natural capacity of this landscape to provide freshwater biodiversity interest. When added to the extensive coastal woodlands and natural streams and rivers running off the valleysides, and the heathlands and grasslands of the adjacent cliffs, further opportunities may arise to develop more missing natural niches required to complete the coastal habitat mosaic of this area.

Further measures to restore a full naturally functioning habitat mosaic in the area should restore some habitat for wetland bird species. However, lost habitat for these species is likely to be best addressed in other localities where restoration of naturally functioning freshwater wetlands has greater spatial scope.

Biodiversity objectives have not been the driving force behind decisions to restore more natural processes in this area, although related objectives (geomorphological interest and climate change) have been major considerations. This case study does however demonstrate the ability of an integrated biodiversity approach based on natural ecosystem function to create synergies with progressive flood risk management and broader climate change adaptation strategies. The small size of the floodplain at Porlock is both an opportunity and constraint – an opportunity because of the limited area affected by restoring natural function, a constraint because of the pattern of human development in that limited area. Further scope for restoring naturally functioning habitat mosaics will require long-term strategic planning and intensive stakeholder dialogue.

Footnote: This work provides a good demonstration of ecological principles 1, 2, 3, 6, 8 and 9 and of practical principles 1 and 2 and 7.

Box 7.7 Integrated biodiversity objectives in Swindale in the Eastern Lake District – Jean Johnston, Lead Adviser, Natural England.


Northern Hay Meadows in upper valley with Melancholy Thistle (Photos: Jean Johnston)

Swindale is a quiet valley on the eastern side of the Lake District. It forms part of the catchment for the Haweswater Reservoir which supplies drinking water to 2 million people in the NW of England. It is owned by United Utilities. The flat, narrow valley bottom is far from natural. The river was straightened (sometime before the 1859 Ordnance Survey map was produced) and most of the fields have been drained and fertilized to varying degrees. The fields that were still species-rich by the end of the 1980s (just 8.2ha) were designated as the Swindale Meadows SSSI. This subsequently became part of the Pennine Dales Meadows SAC. These support the vanishingly rare 'northern hay meadow' plant community with wood geranium, lady's mantle, great burnet and melancholy thistle. It also has species rich purple moor-grass rush pasture, wet grassland with marsh marigold and a range of other mires and swamps. However, even these SSSI meadows are far from pristine and there are also areas of much poorer habitat within its boundaries.

The Swindale Beck flows through the SSSI/SAC meadow and immediately downstream is a United Utilities water intake. Before this was refurbished in 2016, this formed the upper limit for migratory fish and as a result became the upper limit of the River Eden and Tributaries SSSI (and River Eden SAC). The 2km stretch of this beck that had been straightened was rock armoured and had flood banks on both sides. It was uniform, with no opportunities for gravel deposition – so most gravel shot straight downstream and regularly clogged up the drinking water intake. This meant there was a lack of the dynamic habitat variation that is created by an actively meandering river - no deeper pools and shallow riffles with their different bed substrates, no exposed shoals of gravel being created and shifted around, and no natural banks with their variations in slope, vegetation and wetness. This created a lack of habitat for many of the species that are characteristic of this type of river, such as the beetles, nesting birds and pioneer plants of exposed gravel shoals, and the invertebrates and juvenile salmonid fish that need fast-flowing riffle habitat with nearby refuges from flood flows.

The valley sides and uplands above were grazed heavily with sheep for many years and as a result, the heath, blanket bog, scrub and woodland habitats were degraded and fragmented. Some of the blanket bog on the plateau above was also heavily 'gripped' – in other words a network of drains had been dug through it, leading to a lowering of the water table and in some places, erosion of peat. In recent decades, the valley has been managed as one single farm. In 2012, the tenancy was given to RSPB. At the same time they also took on the tenancy of the adjacent Naddle Valley. Both farms have common grazing rights on the nearby upland commons. RSPB's vision is that: "**Haweswater will provide an inspiration for a more sustainable approach to farming in the uplands, providing a broad range of benefits for both nature and people.**"

A partnership approach has been taken to management of the area, with RSPB, UU, Natural England and the Environment Agency all working closely together. A comprehensive restoration programme has been developed for the whole valley and adjacent upland areas. This involves:

- Protection of existing woodland and scrub and planting significant new areas with trees;
- Restoration of blanket bog through grip blocking and removal of grazing;
- Restoration of other upland habitats through reduction in grazing pressure (smaller sheep flocks and increased off-wintering);
- Restoration of hay meadows and pastures through cessation of fertilizer use, restriction of grazing in the spring and (in botanically poorer fields) replanting of wildflowers;
- Restoration of the river habitat mosaic by reinstating active meandering;
- Complete refurbishment of the water intake including installation of much improved fish ladder, opening up the upper valley to migratory fish (complete removal of the weir would have been preferable in ecological terms but this is a major, strategically important water intake to which there is no practical alternative).

The reinstatement of the meandering river was seen as the key to achieving a more dynamic and biodiverse system in the valley bottom. Two days after the new channel was reconnected to the river, there was heavy rain and the whole valley bottom was flooded. Fear about what this would do to the brand new riverbanks proved unfounded and in fact it brought down lots of gravel and shaped it into new bars, riffles and pools, greatly adding to habitat diversity in the river. Salmon redds were discovered in the new riverbed the following autumn. This newly dynamic aquatic ecosystem is mirrored by newly dynamic riparian zones with new areas of gravel and bare ground appearing regularly and providing exciting new niches for a wide range of plant and animal species.

Valley bottom showing old river channel (before it was blocked) and new channel under construction (Photo: Lee Schofield, RSPB)

Blanket bog where grips have been blocked and grazing has been removed

The aim is to continue farming the meadows around the river – and for this reason the river's position has been constrained at one point – to keep access for machinery possible. Other than this it is allowed to move freely. The reinstatement of the meanders - with large machinery - took place through the middle of the SSSI/SAC meadow. The acceptability of this was considered very carefully before proceeding but the two rarest and richest habitats were not directly affected by the works, no plant species were restricted to the area lost to the new channel and the value of the increased dynamism in the system (and therefore potential for new habitats to develop) was viewed as outweighing the small areas of habitat to be lost. In addition, there was a guarantee of appropriate long-term vegetation management and the work was being done in the context of an increasingly healthy valley with a rich, natural source of native seed, no invasive non-natives and virtually no agricultural 'weeds'. Very careful mitigation measures were put in place to ensure that there was no incidental damage during construction.

Overall, the blanket bog is getting wetter and more *Sphagnum*-rich, heathland vegetation is becoming bulkier and more robust, plants previously restricted to the most inaccessible crags may have the chance to spread, there are a lot more trees and shrubs. The hay meadows are floristically diverse, the river is functioning more-or-less naturally and breeding fish have already returned. This all adds up to a catchment that will be a better natural filter that will provide a more reliable source of good quality drinking water and will be much richer in wildlife. Farming continues in the valley and people are very welcome to visit and enjoy it all.

Further details of RSPB's management plan can be seen at:
https://www.rspb.org.uk/Images/HWR-0629-15-16%20Haweswater%20management%20plan%2016pp%20low%20res_tcm9-412269.pdf

Footnote: This work provides a good demonstration of ecological principles 1, 2, 3, 6, 7, 8 and 9 and of practical principles 1 and 2 and 7.

8 Conclusions

The concepts, rationale and principles outlined in this report are relevant to all aspects of Natural England decision-making: how we view the ecological requirements of individual habitat types and species, how we interpret habitat and species inventories, how we notify sites, how we set objectives for those sites and the objectives for habitats and species in the wider environment, how we monitor and report on the distribution and well-being of habitats and species, and how we establish practical protection and restoration strategies at site, landscape and England-scale.

The decision-making principles that have been outlined are not about prescribing local outcomes, but rather they are designed to encourage a certain mindset, a way of looking at sites and landscapes that generates a more integrated picture of what is possible in biodiversity terms. The biodiversity outcomes that are eventually agreed in any given situation will be driven by evaluation of practical constraints and opportunities, and synergies and conflicts with other objectives, through dialogue with a range of partners and stakeholders. The principles encourage a mindset that is innovative and strategic in outlook, being flexible on spatial scale and timescales to secure the most holistic and sustainable biodiversity outcomes with the greatest benefits in terms of natural capital. The approach is therefore highly compatible with Natural England's conservation strategy (Natural England 2016) and can be seen as an important element of technical underpinning for Natural England's Outcomes Approach.

Fully embedding such a mindset in Natural England's specialist advice, guidance, processes and local decision-making is a long-term endeavour, particularly considering that the bulk of our biodiversity-related guidance, and much of the legislation that underpins it, is compartmentalised into habitat types and species. More experienced staff use the flexibility in technical guidance and operational decision-making processes to promote more integrated biodiversity outcomes. Less experienced staff are more likely to use the rigidity in guidance and operational processes as fixed points of reference for reassurance that the right decisions are being made, with less integrated biodiversity outcomes as a result. Overlain on this picture is the importance of audit trails, consistency and demonstrating value for money (VFM) in delivery – rigidity in guidance and operational process delivers strong audit trails, consistency and VFM demonstration, whilst flexibility does not.

All this suggests the need for operational processes to be as flexible as they can be in the short term to help shift mindsets, but for refinements in guidance and processes to be made over time to be more explicit about the importance of naturally functioning habitat mosaics for delivering integrated biodiversity outcomes. Natural England habitat and species specialists have major role to play in this, in providing their real-time advice within the more integrated framework outlined in this report, and in refining specialist guidance over time. The forthcoming Ecological Networks Handbook (Natural England In Prep.) provides an important starting point for progressive technical guidance that properly embeds the concept of natural ecosystem function.

9 References

Note that reference lists for individual broad habitat types are provided in the appendices.

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General introduction to the appendices

Habitat-based appendices are provided as separate documents. All of the appendices reflect the same general structure below:

1. Habitat variation – brief explanation of broad types

2. Factors affecting ecological position in the landscape – starting with abiotic factors and moving on to biotic factors, using a reference point of natural processes.

3. Ecological function and relationships – for each broad type, how abiotic and biotic processes shape the habitat and its assemblages, using a reference point of natural processes. Explain micro-habitat mosaics within the habitat, classical hydrological/hydrochemical transitions at larger scales, vegetation successions and interruptions to them. Explain importance of the habitat to the species utilising it.

4. Current level of natural function – for each broad type, how has human influence modified distribution and to what extent is the habitat resource functioning naturally according to the five pillars of natural function, using expert judgement and the table below.

State of naturalness	Prevalence of state within the habitat resource (indicate high, moderate or low prevalence)				
	Hydrology	Nutrients	Soil/ sediment	Vegetation control	Species composition
Good					
Intermediate					
Poor					
Confidence					

5. Scope for restoration of natural function – consider the feasibility and desirability of restoring different elements of natural function, and assess the biodiversity benefits and potential risks. Consider both high value and degraded examples of the habitat, as well as land parcels not currently within the habitat resource (i.e. habitat creation). Using expert judgement and the table below.

	Hydrology	Nutrients	Soil/sediment	Vegetation control	Species composition
Desirability (Y/N/sometimes)					
Comments					
Biodiversity synergies/conflicts					

6. Provision of habitat for species - Describe the use of the habitat by characteristic and priority species – small-scale habitat mosaics, role of natural function. What are the implications of restoring elements of natural function in terms of habitat provision for characteristic assemblages and individual priority species? Big habitat losses, big gains? What are the implications of the expert judgement made in (5)?

7. Key messages