Chapter 10 Restoration and creation of floodplain meadows

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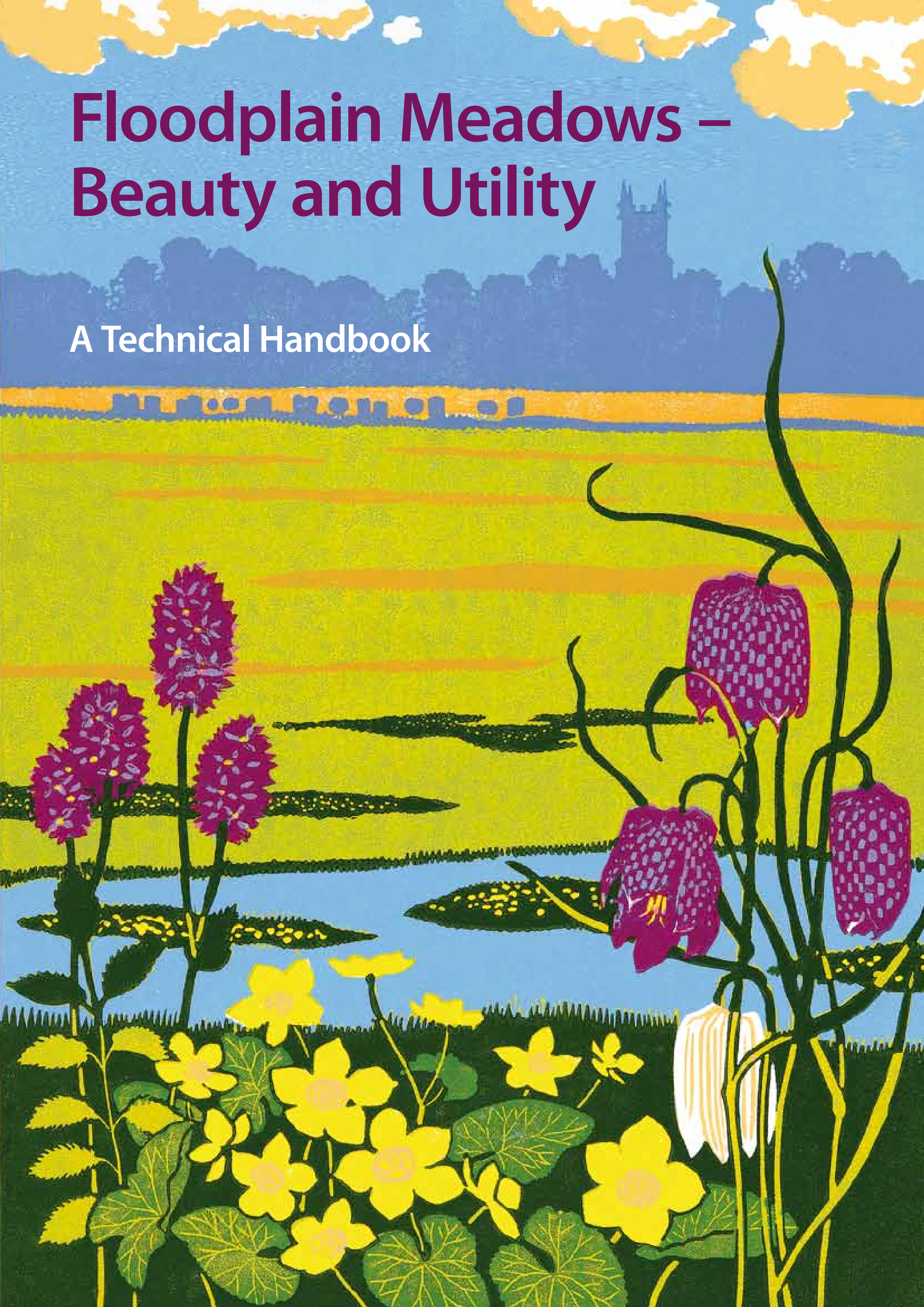
Floodplain Meadows – Beauty and Utility

A Technical Handbook



Floodplain Meadows – Beauty and Utility. A Technical Handbook

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Preface

In Shakespeare's play *Henry V*, there is a scene, after the battle of Agincourt, where the captured Duke of Burgundy is lamenting the cost of war. He does this by conjuring up before our eyes a picture of what happens to a meadow when the men have gone off to battle and the fields lie neglected with no-one to mow them.

> *The even mead, that erst brought sweetly forth*
> *The freckled cowslip, burnet and green clover,*
> *Wanting the scythe, all uncorrected, rank,*
> *Conceives by idleness, and nothing teems*
> *But hateful docks, rough thistles, kecksies, burs,*
> *Losing both beauty and utility.*

Just how much time Shakespeare spent in his birthplace of Stratford is a subject of argument but what we cannot deny is that he had carefully noted what really happens in the kinds of meadow once commonplace along river valleys like the Warwickshire Avon, when the hay goes uncut. Colourful plants such as the cowslip, great burnet and white clover, characteristic of the regularly mown grassland, denied the scythe, are overwhelmed by tall umbellifers (the kecksies), docks, thistles and burdock, plants more familiar to us from neglected waysides, grown unkempt.

Such meadows as Shakespeare observed came about for practical reasons: on the fertile soils of regularly flooded lowland valleys, they yielded valuable herbage, cut in summer when the fields were dry and stored as hay, to keep animals fed during the winter cold when nothing grew. Their visual delight, though appealing to the playwright's eye and ours – and maybe even, we might say, to the mower's – was a by-product of this regular treatment, but the characteristic of floodplain meadows is that beauty and utility were, and are, combined in that sustainable management. And it was the loss of both, in the neglect that came with conflict, that the Duke of Burgundy lamented.

In nature conservation, it is beauty that has usually driven our concern – or at least those values of wildlife, habitat and landscape that are not so readily costed in terms of productivity or cash, maybe not even simply totalled up as this or that number of species or sites that remain now. We might even think that the creatures of the floodplain meadows, the plants and the animals that characterise them, though brought together by human influence as a distinctive habitat, have value all of their own, no matter what they might be worth to us.

Yet, almost nothing that we now value and sustain for its wildlife interest was produced by nature management, and most habitats have come about through complex relationships with the lives and livelihood of people interacting with the soils and climate of particular places, and earning their living thereby. And that gives them cultural significance, too. Trying to understand such a complex and fine balance is what the Floodplain Meadows Partnership is all about. It has been an exceptional example of how painstaking vegetation survey, quality scientific research and a sensitivity to local communities and their history of involvement with the landscape can come together in understanding and celebration of one of our glorious national assets.

The richness of information and practical guidance in this book is a testimony to the achievement of the project team and their partners across the country, rightly recognised by the financial support they have repeatedly attracted for the quality and commitment of their work. You can be guaranteed here to find facts and inspiration, encouragement and direction to take up the call for floodplain-meadow restoration through a project in your own community, building local partnerships or by supporting national campaigns. A combination of science and culture – beauty and utility indeed.

John Rodwell

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Chapter 1
Introduction

Emma Rothero

> ***"By flow'ry meads on each side of its banks***
> ***The Ouse, well stocked with fish, runs through the town"***
> (from *Eboracum* by Alcuin, 8th century)

Floodplain meadows are beautiful, ancient and fascinating places rich in wildlife and history. Throughout the spring and early summer, they are awash with wildflowers and waving grasses, humming with insects and the birds that depend on them. They provide a vibrant and beautiful spectacle that has now all but disappeared from the UK.

Floodplain meadows evolved over many hundreds of years through the need to store the summer grass crop as hay to sustain cattle, sheep and especially horses over the winter months. The system of allowing the vegetation to grow up in the spring, taking a hay crop in midsummer and then grazing the re-growth prevented taller, coarser species from becoming dominant and created the diverse flower-rich sward we see today. Once valued primarily for their key role in commercial agriculture, the few remaining species-rich floodplain meadows are now valued for a wider set of attributes.

Floodplain meadows:
- generate a sustainable and prized hay crop;
- provide an important nectar source for pollinating insects such as bumblebees and hoverflies;
- support rare plant communities and are vital sources of seed for the restoration of meadows;
- provide flood-storage areas, trap sediment and store carbon, and will be increasingly valued for these functions as the climate changes; and
- provide a link with the past, a living reminder of the traditional, rural landscapes and the ways of life that created them.

A more detailed discussion of the value and history of floodplain meadows is found in Chapter 3. More information on the distribution and conservation of floodplain meadows in the UK can be found in Chapter 4.

Floodplain meadows are often older than parish churches, and were so important in medieval times to rural communities that they were valued many times more highly than arable land (Brian and Thompson 2002). © Mike Dodd

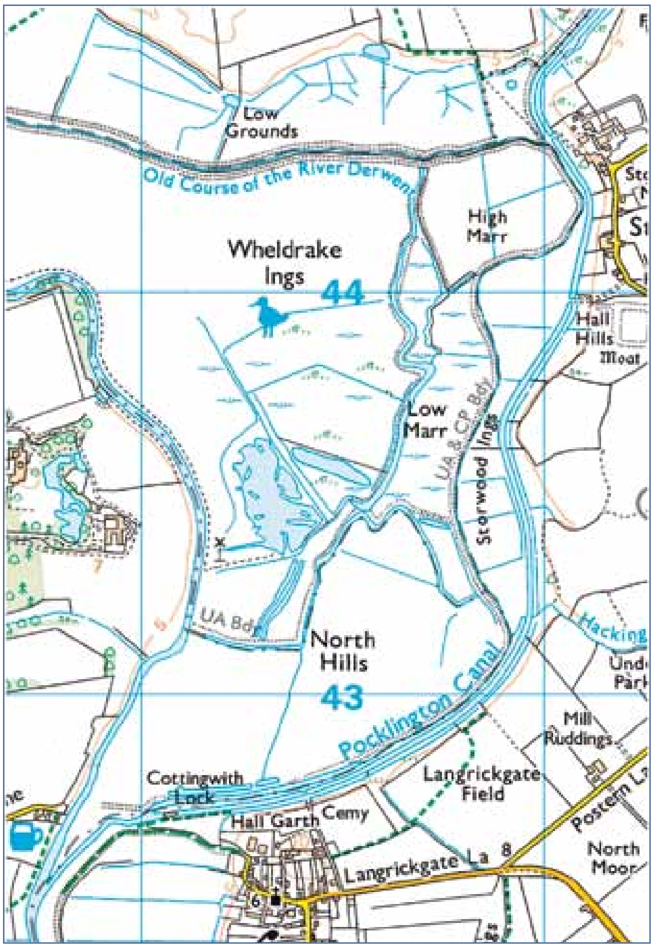
The Oxford Meadows in flood. © Mike Dodd

Floodplains are defined as low-lying ground bordering a river, formed mainly from sediment deposited during flooding. Where natural flooding still occurs, floodplains may be managed as pasture (used for livestock grazing) or as meadows (cut for hay or silage and then grazed). Most floodplains have been greatly altered by drainage and the creation of flood defences and, where flooding is prevented, floodplains are often used for arable crops or have even been developed.

What are floodplain meadows?

Floodplain meadows are areas of grassland used for hay making (and after the hay is cut, for a range of other activities including grazing, horse racing, fairs or ice skating) that are periodically flooded by an adjacent river or stream, or have a plentiful groundwater supply through gravel or sand aquifers.

Figure 1.1 Most floodplain meadows are bounded by watercourses as they usually lie between the river or stream and a back drain often historically dug to help drain the meadow. Wheldrake Ings, part of the Derwent Ings SSSI and Lower Derwent Valley SAC. © Crown Copyright and Database Right [December 2015]. Ordnance Survey (Digimap Licence).



In cases where the river has been embanked, floodwater may sometimes still enter the site from the back drain. Water regimes can therefore vary across a meadow, and this variation differs between sites depending on the main source of floodwater. This results in very different patterns in the bands of vegetation that develop. Chapter 8 provides descriptions of different vegetation communities found and their hydrological requirements.

Floodplain grasslands developed under an agricultural management that included an efficient surface drainage system. Many sites also rely on subsurface drainage provided by shallow seams of underlying sand or gravel (Gowing, Lawson *et al.* 2002). This is important in allowing floodwater to drain away rapidly. Chapter 7 explores the water requirements of floodplain meadows.

The nature of the drainage also depends on soil type. The classic soil profile of floodplain meadows is one of alluvium (silt deposited by floods) lying over a coarser deposit such as gravel. Less often, floodplain meadows are found on peat soils where drainage is governed by a system of shallow gutters connected to drains surrounding each field. Peat sites tend to have a higher summer water table and are more likely to support the plant communities typical of damper conditions. Where mineral and peat soils meet, a different pattern of plant communities may be found, as at Moorlinch and Wet Moor on the Somerset Levels where the peat has a clay topping. The nutrient dynamics of floodplain meadows are also important in shaping the vegetation. The removal of the hay crop results in a loss of fertility, which is then balanced by the sediment deposition and nutrients from floodwaters. Chapter 6 provides more information about floodplain-meadow nutrient cycles.

Evolution and historic management

Woodland clearance during the Neolithic period (c. 4,000 to 2,500 BC) probably resulted in a rise in floodplain water levels. The intensification of cultivation in upper catchments during the Iron Age (c. 800 BC–50 AD) and the Roman period (c. 50–AD 410) may have increased silt and water run-off and led to greater deposition of alluvium on land adjacent to rivers. This may have accelerated the development of large expanses of flat floodplain through the infilling of old river channels and stream beds with silt (McDonald 2007a).

Floodplain meadows differ greatly in size, ranging from just a few hectares (e.g. often those adjacent to a small stream that still receives floodwaters) to several hundred hectares (e.g. those associated with major river systems). Left: North Meadow, a medium-sized floodplain meadow (44 ha) and National Nature Reserve in Wiltshire. © Rob Wolstenholme **Right: Yarnton Meadow, a larger floodplain meadow (86 ha), Oxfordshire.** © Mike Dodd

Once riparian woodland had been cleared, mire vegetation probably dominated on floodplains. Increased silt deposition and the development of active farming, including drainage and the introduction of mowing and grazing, led to the development of floodplain grassland. It is thought that typical floodplain meadows are around 1,000 years old. Since then, a long history of traditional management has resulted in the distinctive character of floodplain meadows as we know them today. This historical management is described in Chapter 3.

Management, restoration, creation and monitoring

One of the objectives of this handbook is to raise awareness of the sensitivity of floodplain-meadow plant communities to changes in water level, management and soil fertility to help conserve the few remaining species-rich floodplain meadows. The handbook is also a call to arms to prevent further fragmentation of this habitat and encourage restoration and creation where possible. In addition to providing new habitat, this will increase the resilience of the existing areas. Chapter 9 and Chapter 10 provide information on these aspects and include relevant case studies.

Monitoring of sites and new projects is necessary to increase understanding, determine success and identify problems. Chapter 11 provides guidance on how to go about monitoring and interpreting the data collected.

Monitoring soil: measuring water levels in a dipwell using a buzzing stick. © Emma Rothero

Using this handbook

This handbook provides practical information about managing and restoring floodplain meadows, with an emphasis on case studies and examples. This is combined with relevant technical information to facilitate background understanding of the issues involved. The information has been collated through many years of scientific study carried out by the Floodplain Meadow Partnership and through its links to restoration and community-based projects across the UK. It is intended to be accessible and informative for anyone managing or restoring floodplain meadows, or with an interest in the many other important aspects of floodplain meadows that are touched upon.

Nomenclature

The plant nomenclature used in this handbook follows the third edition of the *New Flora of the British Isles* (Stace 2010). Vernacular names are used in the text, with scientific names given in the Nomenclature. Vernacular names are also used for NVC communities (see box). These are based on those developed by John Rodwell for the Countryside Council for Wales (now Natural Resources Wales).

The National Vegetation Classification (NVC)

In this handbook, the NVC is used to help describe plant communities in terms of their typical species composition, management history and environmental requirements. However, the value of floodplain meadows lies in the mix of botanical diversity, social history, sustainable agricultural function and broader benefits, so the NVC should not be used prescriptively or as a rigid target for restoration.

The NVC is the standard classification system used for describing vegetation in Britain. It is published as *British Plant Communities* in a five-volume set, Volume 3 of which deals with grasslands (Rodwell 1992). The section on neutral (mesotrophic, 'MG') grassland communities includes those of floodplain meadows.

The NVC is a phyto-sociological classification – it segregates vegetation into types on the basis of the presence and relative abundance of plant species. The resulting plant communities can usually be correlated with other factors, particularly geology, hydrology, soils and management.

Within the NVC, the definition of communities and sub-communities is based on the species content of a very large number of samples. The samples are analysed and grouped (e.g. using Twinspan[1]) according to the species present and their abundance. Each group can then be characterised by the constancy (frequency of occurrence) of each species within it and their abundance (percentage cover expressed as DOMIN ranges). Each group (community or sub-community) will have a number of species that are always, or almost always, present, together with a much greater number of species that are more rarely present. The high-frequency species are used to identify the communities. Further information on NVC can be found in the relevant volume and the *National Vegetation Classification: Users' Handbook*[2] (Rodwell 2006).

Additional plant communities (and sub-communities) have been, and are being, recognised since the final volume of *British Plant Communities* was published in 2000 (e.g. Rodwell *et al.* 2000). This handbook includes descriptions of several such communities/sub-communities that occur on floodplain meadows (see Chapter 8).

Important: permissions, consents and permits

Some management, restoration and creation activities described in this handbook may require permission from Statutory Agencies such as the Environment Agency, Natural England, Natural Resources Wales, Scottish Natural Heritage and/or the Local Planning Authority. It is vital that, before planning and undertaking such activities, checks are made to determine what consents and permits may be needed to ensure work is carried out within the law.

Advice should also be sought for any ground works as part of a management or restoration scheme to ensure there is no damage to archaeological features.

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[1] http://www.ceh.ac.uk/services/decorana-and-twinspan

[2] http://jncc.defra.gov.uk/pdf/pub06_NVCusershandbook2006.pdf

Chapter 2

The wildlife of floodplain meadows

Emma Rothero and Sophie Lake

Consistent agricultural management has created a rich wildlife habitat on floodplain meadows. A range of taxa (most notably invertebrates and birds) is supported by the dynamic mix of different plants. In most cases, the species present are those either adapted to, or relatively unaffected by, the changes brought about by hay cutting and seasonal flooding.

The plants and vegetation of floodplain meadows

Origins

Before human activities began to reshape the environment, valley bottoms and river banks would generally have supported wet woodland. On peaty substrates, this probably resembled Sallow-birch fen carr (W2) or Hoary birch woodland (W4) while on mineral soils, it would have been similar to a mixture of Sallow marsh woodland (W1) and Alder-ash flush woodland (W7). The deepest riverside sediments probably supported strips of more fertile Alder-nettle floodplain woodland (W6).

Following woodland clearance from the Neolithic period onwards (see Chapter 1), it is likely that these communities were replaced with floodplain mires dominated by bulky sedges and rushes. Subsequently, increased agricultural activity included the drainage of such mires. Once drainage had lowered the water table, mowing and aftermath grazing was introduced, and floodplain-meadow communities developed (Jefferson 1997).

The scarce snakeshead fritillary is found in Burnet floodplain meadow (MG4), as well as on some less species-rich sites in the UK. © Mike Dodd

Modern plant communities

The plant community most typical of traditionally managed floodplain meadows is the Burnet floodplain meadow (MG4) (see Chapter 8). In terms of plants, this type of vegetation is one of the most species-rich grassland communities found in the UK. The Floodplain Meadows Partnership has recorded quadrats with up to 43 species per m^2 (Wallace and Prosser 2015), making this one of the richest neutral grassland habitats in the UK. Floodplain-meadow plant communities may also contain nationally scarce species such as snakeshead fritillary, downy-fruited sedge, narrow-leaved water-dropwort and a number of unusual dandelion micro-species. There is a geographical difference in the presence of some plants; for example, wood anemone is found on northerly sites, but not typically southern sites (Jefferson and Pinches 2011).

Burnet floodplain meadow (MG4) often exists in a complex mosaic with other grassland communities in a pattern which reflects the hydrology of the site. These communities include Kingcup-carnation sedge meadow (MG8), Foxtail plash (MG13) and Knapweed meadow (MG5) and the more recently described Sedge lawn (MG14) and Cuckooflower grassland (MG15p) and are described in Chapter 8. Other related communities such as mire and swamp communities and species-poor grasslands are described in the Appendix.

Special plants

Two plants of particular interest are often associated with floodplain meadows. Burnet floodplain meadow (MG4) is the principal community in Britain for **snakeshead fritillary**. It is now a rare species, found on less than 30 sites in the UK where it is considered to be wild. **Narrow-leaved water-dropwort** is more closely associated with damper examples of the Burnet floodplain plant community, and can persist even under moderately heavy grazing and raised fertility. Both plants were included in the vascular plant red data list for Great Britain where they are described as nationally scarce (Cheffings and Farrell 2005). However, snakeshead fritillary is on the 'waiting list' in the Vascular Plant Red List for England (Stroh *et al.* 2014) due to doubts over its native status[3]. Narrow-leaved water-dropwort is described as near threatened in Great Britain according to 2001 IUCN guidelines (Cheffings and Farrell 2006), although it is categorised as of least concern for England (Stroh *et al.* 2014).

The snakeshead fritillaries at North Meadow NNR have been counted since the 1970s by Natural England, the Floodplain

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[3] Work is ongoing looking at the DNA structure of the snakeshead fritillary in order to determine its origins.

Meadows Partnership and volunteers. This study, which uses fixed-point quadrats to sample the population, has revealed a strong relationship between the presence of plants and flooding in the previous season. For example, in 2012, exceptional floods meant that the meadow was underwater almost continually for ten months; the following year, only five plants were found in a search of 200 1 x 1 m^2 quadrats (1,800 plants had been recorded in the pre-flood count). In 2014, plant numbers were back to over 1,000, although a much higher percentage of vegetative plants were counted compared to flowering plants. This demonstrates that the species responds to extreme conditions with a period of dormancy.

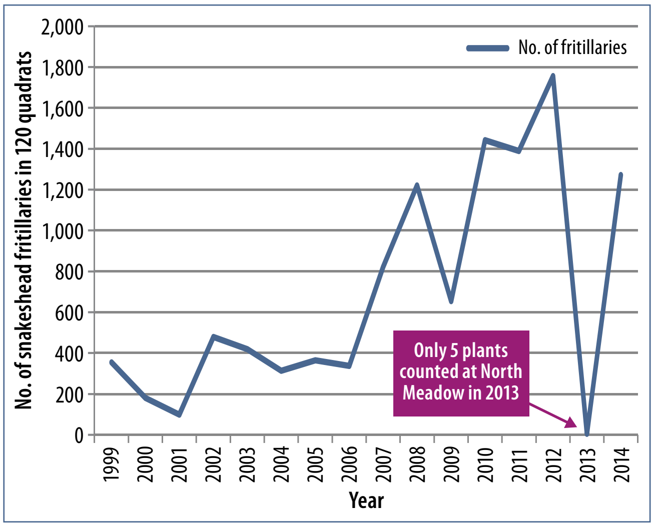


Figure 2.1 Fluctuations in the size of the snakeshead fritillary population at North Meadow, Cricklade.

Narrow-leaved water-dropwort is a nationally scarce species and has been recorded from 49 tetrads since 1970 with large populations on the Lugg and Hampton Meadows (Herefordshire), Upton Ham (Worcestershire) and Ashleworth Ham (Gloucestershire). © Mike Dodd

Eighty percent of the UK's population of snakeshead fritillaries are found at North Meadow National Nature Reserve in Wiltshire. © Mike Dodd

Invertebrates

Floodplain meadows provide habitat for invertebrates in a range of ways. They offer a significant seasonal resource of pollen and nectar for a large number of species that are generalist in their feeding habitats, particularly as adults. Bumblebees, sawflies, hoverflies and various beetles, including many of which are in global decline (Potts *et al.* 2010), can be abundant. Floodplain meadows also offer habitat for more specialist flower-feeding insects that require particular flowering plants, either to complete their larval stages or as the main food plant for adults. Additionally, ground beetles (some of which can survive flooding for months), spiders and invertebrates such as true bugs and leafhoppers living on plant stems, leaves and roots add to the diversity.

Invertebrates benefit overall both from structural and plant diversity within a grassland type and from a diversity of grassland types in the landscape i.e. a mosaic of meadows, pastures, road verges and hedge banks. There is a perception that pastures are better than meadows for invertebrates because the meadow habitat is largely lost when the hay is cut. However, meadows are uniquely rich nectar sources during the flowering period, and many species (particularly hoverflies and weevils) rely on such sources of food. In addition, uncut margins provide an ongoing resource. Moreover, some species groups are not affected by the hay cut, either because they live in the ground or because they have completed the life stages dependent on standing vegetation. These species groups may do better in meadows than pastures.

The sawfly *Abia sericea* distribution is restricted to its host plants (devil's-bit scabious or field scabious). © Judy Webb

A nationally scarce click beetle *Ctenicera pectinicornis* found on Yarnton West Mead in 2015, not previously recorded on the site or in Oxfordshire. © Judy Webb

Many species of moths and butterflies use meadows at all stages of their life cycle, including chimney sweeper and burnet moths (such as the six-spot burnet shown here) and orange-tip and small copper butterflies. © Mike Dodd

The loss and fragmentation of flower-rich semi-natural grasslands, including meadows, is considered to be one of several key factors in the decline of bumblebees (Carvell *et al.* 2006). The common carder bee (seen here) is an example of a generalist pollinator, which uses flowering plants of floodplain meadows at key times of year. © Mike Dodd

Curlew can breed successfully in floodplain meadows provided the hay is not cut until the chicks have fledged. © Mike Dodd

Birds

Floodplain meadows provide a rich habitat for a range of birds throughout the year. During the spring and summer, larger sites in particular can be important for breeding waders such as lapwing, curlew, redshank, snipe and black-tailed godwit, providing ground nesting habitat and soft feeding grounds. Skylark may also nest in floodplain meadows, and yellow wagtail is particularly attracted to sites where cattle are grazing. Depending on the local landscape, a number of small birds will use floodplain meadows, particularly where there are areas of scrub or hedgerows on the drier ground.

At other times of the year, especially during and after periodic flooding, floodplain meadows provide feeding grounds for a wide range of wildfowl and waders, including whooper swan, Bewick's swan, wigeon, teal, shoveler, golden plover and snipe. Winter flooding, or even temporary inundation, provides feeding grounds for wildfowl and waders from countries further north, making these meadows important on an international scale. Key sites have been designated as Special Protection Areas and/or Ramsar sites under European and international directives and conventions for their bird populations. Most of these species have declined significantly in recent years and are now classified as 'of conservation concern' (Eaton *et al.* 2009). Many have become locally extinct as a breeding species, such as snipe along the Severn catchment in England (Balmer *et al.* 2013).

Floodplain meadows also provide year-round feeding grounds for small passerines that rely on seeds and invertebrates, and feeding and roosting habitat for wintering species such as starling, redwing and fieldfare.

Floodplain meadows can provide good habitat for moles when not flooded, although they are clearly used throughout the year as this picture shows (Yarnton Mead, Oxfordshire). However, historically moles were viewed as a pest species because of the perception that their burrowing undermined banks and because molehills interfere with the hay-making process. Molehills were flattened with horses and a moulding sledge as one record shows from 1775 (Hammond 1995). © Mike Dodd

Mammals

Small mammals such as harvest mouse, field vole and common shrew may use floodplain meadows during the spring, when the meadows are allowed to grow for hay. However, this provides only short-term opportunities as the subsequent cutting and grazing render the habitat largely unsuitable; unless pockets of tussocky grassland and taller herbs are managed on a longer rotation within the mosaic, populations of small mammals are unlikely to remain after the hay cut. Grasses left to grow taller adjacent to hedges and watercourses may be attractive to harvest mouse, which builds an aerial nest in common reed, reed canary-grass and cock's-foot.

The close proximity of rivers and their associated ditches and dykes provide a well-connected network of riparian habitats that benefit otter, water vole and water shrew. Otter populations declined dramatically in the latter half of the 20th century, but their numbers are now recovering well in all but the south-east of England and there are good prospects for a full recovery in the next two decades (Crawford 2011). Otters use rivers for commuting and foraging. Whilst they feed mainly on fish, they are opportunistic hunters and the wetter areas of floodplain meadows are likely to support good numbers of frogs in spring, providing them with an alternative food source.

Prime sites for water voles occur along open grassy, vegetated banks of ditches, rivers and streams where water is present all year round. The introduction of the non-native American mink has had a serious impact upon water vole populations through predation (Halliwell and MacDonald 1996), but they are also affected by fluctuating water levels and overgrazing of bankside vegetation. The provision of year-round refuge areas with a thick fringe of waterside plants will encourage healthy populations of water vole, particularly where mink numbers are restricted by trapping (Woodroffe 2006).

Plant diversity within floodplain meadows encourages a range of invertebrates, particularly early in the season, and the associated rivers are also insect-rich habitats. Bats depend wholly on insects for food, hunting along river corridors and over grassland. A number of generalist bat species are recorded as foraging within this landscape (Moore *et al.* 2006), but Daubenton's bat is strongly associated with freshwater habitats and the soprano pipistrelle has also been linked with riverine features. The larger noctule prefers to hunt over pasture and meadows, particularly where there is nearby woodland for roosting. The barbastelle bat feeds within a range of habitats including damp grassland in lowland river valleys, so floodplain meadows may provide important foraging habitat for this scarce bat.

Many thanks to additional contributors Sarah Blyth, Simone Bullion, Martin Hammond, Toos van Noordwijck, Alan Shepherd and Judy Webb.

A recent study in Suffolk found a strong association between rivers and the presence of harvest mouse in the landscape (Meek and Bullion 2012). © Mike Dodd

Chapter 3

History and changing value of floodplain meadows

Emma Rothero

This chapter provides a long-term look at floodplain meadows, how they originated, how they have been sustained and how society's evaluation of them has changed over time. The different types of floodplain meadow are defined, and the way they are valued today is explored. Tips and ideas for researching the history of a floodplain meadow are given and case studies show examples of historical research on three floodplain meadows in the UK.

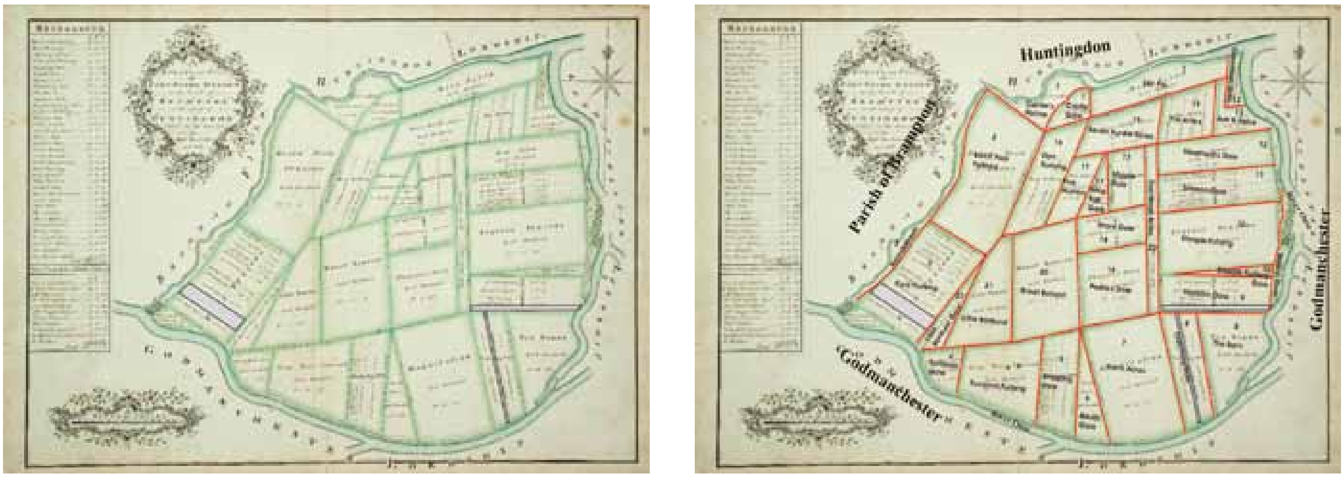
Floodplain meadows exist because they were an essential element of the agricultural system on which rural communities depended. Floodplain-meadow management evolved to take advantage of the replenishment of nutrients through flooding in order to produce a good hay crop. These meadows were valued historically for their productivity; more recently, other benefits to society have begun to be more widely acknowledged. Traditional management created beautiful meadows with a diverse flora and associated ecology, places which provide opportunity for rest, inspiration, appreciation of aesthetic beauty, quiet reflection and spiritual experience, values that are today considered to be important in a world less in touch with the land. The flood and carbon storage provided by floodplain meadows, and their productivity during droughts, may also help human society adapt to predicted climatic extremes.

An understanding of the history of a floodplain meadow brings a much deeper perspective of its value and its place in the local community. It may also help to inform future management. The process of increasing historical understanding can also promote wider community engagement with a site (particularly on sites where the botanical interest is currently relatively low).

Ancient meadows

Many floodplain meadows are ancient. Archaeological evidence points to pastoral systems being in place on the Oxford meadows as far back as the Bronze Age (2,500–800 BC) and continuing into the Iron Age (800 BC–43 AD). There is evidence that, by the time of the Roman occupation

Figure 3.1 Enclosure maps from 1772 indicate that the management pattern of Portholme Meadow, in Cambridgeshire (Brampton), was very similar to that of today (the red lines on the second image indicate current hay lots at Portholme, drawn by Pat Doody from the sale particulars (Doody 2007)). There is no definite record of how the site was managed before that date. Case Study 3.5 reveals more detail about the current and historical management of Portholme Meadow.



At the time of Domesday "the floodplain meadows of the Lower Lugg Valley were extensive and much the largest in the County of Herefordshire" (Brian and Thompson 2002) and were likely to have been in existence long before then. © Sue Holland of Britain (43–410 AD), floodplain grasslands were cut for hay (Hammond 1995; Brian and Thomson 2002; McDonald 2007a). For example, parts of the Ouse Ings (in Yorkshire) were being managed for hay as early as the 2nd century AD (Hammond 1995). Hay making was a well-established management practice in Saxon times (7th–9th centuries). By Norman times, meadows were recorded in many settlements in the Domesday Book of 1086 (Brian and Thomson 2002; McDonald 2007a) and were valued more highly than arable land.

Later historical references to floodplain meadows can also be found; some of the Lower Derwent Valley (Yorkshire) was classified as 'meadow' as early as 1225 (Milsom 2006). Hemingford Grey Meadow in Cambridgeshire was first recorded in 1563, and is still managed as a meadow today (Smith 2007).

The rural economy

Meadows played a crucial role in the farming economy (Green 1990). The production of hay allowed animals to be kept over winter, while their manure fertilised the arable fields. Hay provided winter feed for the oxen and horses essential for farming practices and for the livestock reared for meat, milk, wool and leather. Floodplain meadows were particularly highly valued because the nutrient-rich silt deposited by floodwaters meant that they were very productive and the hay had a high mineral content. This explains why they were the most expensive type of land recorded in the Domesday survey (McDonald 2007b; Brian and Thomson 2002). A specific example involves Lugg Meadow in Herefordshire. At the time of Domesday, ownership of Lugg Meadow was divided between the King, the Bishop and Cathedral clergy. Lugg Meadow hay was considered to be such a great source of wealth that without this income the rebuilding and maintenance of Hereford Cathedral could not have taken place (Brian and Thomson 2002).

Traditional management of floodplain meadows

The historical agricultural management of floodplain meadows involved hay cropping followed by grazing of the re-growth (known as 'aftermath'), although sometimes a double hay cut was taken in place of grazing. This system made the most effective use of floodplains. In some cases the hay cut was shared between manorial tenants (e.g. see Case Study 3.1), who were allocated particular strips of meadow, and was then followed by communal grazing. Such a system was found across the UK from at least medieval times onwards, and is still found on a handful of meadows remaining today. These are known as Lammas meadows (see box).

Lammas meadows

A Lammas meadow is a meadow registered as being common land between Lammas (1 August) and Candlemas (1 February) each year. Lammas means 'loaf mass' and the day marked the start of the corn harvest. After Lammas, commoners were able to graze their livestock over the whole meadow until it was shut up for hay (i.e. grazing animals were excluded) in February. In the summer, commoners were entitled to cut hay from the strips or parcels of the meadow (known as customary acres, doles or lots) that had been allocated to them. In most cases, the strips included both high quality and poorer quality areas of the meadow, to ensure everyone had a fair share (Warburton 2006). In some places, such as Oxhey[4] Mead near Oxford, the lots were allocated each year where the hay rights were drawn in a lottery (see Case Study 3.3).

At North Meadow, Cricklade, the hay lots were sold to individuals, with each farmer responsible for cutting and harvesting the same parcel of land each year. After the hay cut, the aftermath, or second flush of grass, was again communally grazed until conditions became too wet, when livestock were taken off to higher, drier ground.

True Lammas meadows have a commoners' association, which manages the communal grazing rights, and have some form of strip markers or dole stones to mark the position of hay strips and/or ownership. For example, Lugg Meadow has two commoners' associations – one for Upper Lugg and one for Lower Lugg. They still meet annually to agree a date for opening the meadows for common grazing, agree annual tolls and to appoint a haywarden (or hayward) whose job involves keeping a tally of the numbers of animals and their welfare. Other floodplain meadows are managed in a similar way, but may not be registered as common land or have a commoners' association or marked strips.

The names on these cherry wood balls dating from 1279–1317 are still in use today. Each represents the property (now person) entitled to hay (McDonald 2007a). © Alison McDonald

Given that the population was largely illiterate, a system of symbols was devised to show the ownership of hay lots. This system was used on various Lammas meadows. Some of the symbols reflected the occupation of the tenant, for example, a cross for Church property (Brian and Thomson 2002).

⊙	Duck's nest
⊏	Two in right, one at head
∴	Three pits brandierwise
⁙	Four oxen and a mare
♀	Dung pick
T	Headless
†	Cross

— — —	Three score
↑	Crane's foot
6	Horn
•|	Pole-axe
⫯	Pele
◡	Oven
◈	Crown
○○○○	Four pits

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[4] Now known as Oxey Mead.

Meadows in rural life during the 19th century

The whole community was often involved in hay making, including children. Archive records from 1874 for Hemingford Grey Meadow show that there was only a: "…*small school through the week [with] bird scaring in the cherry orchards and hay making the chief causes of absenteeism*". In 1889 when the hay harvest was late (21 July) the records state that: "…*the attendance is still poor; the hay harvest is in full swing and many children are away in consequence*".

The animals which underpinned the rural economy had to be fed. Warburton (2006) described the Derwent Ings as: "… *the equivalent of the village petrol pump and hay was the petrol*".

Image (right) is from Wheaton Aston in Staffordshire from a cutting provided by Wes Wheate. © John Rodwell

Value and benefits of floodplain meadows today

Today, there is interest in understanding and quantifying the value and benefits offered to society by habitats such as floodplain meadows. These are summarised in Table 3.1, and where possible quantified and clarified with examples in the relevant chapters.

Cultural benefits of floodplain meadows

The cultural associations, benefits and value of floodplain meadows, and indeed any wildlife habitat, can be very complex and difficult to quantify. Our relationship with the surrounding land, its historic and current management and visual appearance are closely integrated with our sense of who we are, and for many of us, have inspired our lives.

Many people love to visit sites with fabulous wildflower displays. Some visitors also find such displays of flowers, the moving waters of floodplains, their birds and the passage of the seasons over the whole landscape an inspiration for

Water meadows

The term water meadow denotes a floodplain meadow with a very specific traditional management system. Water meadows often support Kingcup-carnation sedge meadow (MG8; Rodwell 1992) or a form of Cuckooflower grassland (MG15p; Page 1980) (see Chapter 8), and the term is sometimes used to refer to such vegetation communities; here the term water meadow is used to refer to the land use rather than the vegetation.

Water meadows were carefully flooded to provide an early bite for livestock by enriching the sward. The most complex systems included artificial channels (fed from a dammed stream), drains, sluices and other structures. These were used to divert river water onto the meadow and allow a carefully regulated flow of water to trickle over the sward before being drained back into the associated river or stream.

Documentary references suggest that water meadows were used, in some form, during medieval times, though very little is known about early systems. It is from the early 17th century onwards that complex 'bedwork' water meadows (with feeder channels running along parallel ridges and drains in the furrows between them) were laid out in many English river valleys. This was particularly the case in central southern England, where c. 100,000 acres of water meadow are thought to have been constructed by 1850.

Water meadows were expensive to create and often required the services of expert 'drowners' to operate and maintain them so, unlike Lammas meadows or other floodplain meadows, they were often managed directly by large estates. They became uneconomical from the late 19th century onwards and only a handful of working examples survive today. However, the ridge and furrow profile of derelict examples may still be seen in some river valleys.

Further information

- Available from Historic England's website: *Introductions to Heritage Assets: Water Meadows* by N. Smith and P. Stamper (English Heritage 2013) and *Conserving Historic Water Meadows* by N. Smith (English Heritage 2014[5]).
- *Water Meadows: living treasures in the English Landscape* by M. Everard (Forrest text, Cardigan 2005).
- The formation and maintenance of water meadows in Hampshire, England by J. Sheail (*Biological Conservation* 3 (2) 101–106, 1979).

Water meadow at Amesbury , Wiltshire. © Nicky Smith

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[5] https://historicengland.org.uk/images-books/publications/iha-water-meadows/

art, craft, writing and music. Cultural landscapes such as floodplain meadows also often engender a strong feeling of links with the past. Researching local history and community memories is one way of appreciating and celebrating such a feeling of belonging and of sharing information about how landscapes and people have shaped one another. Sometimes people also gain real spiritual value and perhaps life-changing experiences in natural surroundings, and may speak of particular moments of delight and wonder or cherish how their sense of well-being is improved. Visits to species-rich floodplain meadows are also likely to bring health benefits – access to green space and experience of locations with greater species-richness have both been correlated with indicators of health and well-being (e.g. Groenewegen *et al.* 2006; Fuller *et al.* 2007).

The cultural benefits of floodplain meadows are hard to quantify. At some sites, they could perhaps be quantified in terms of the numbers of visitors to the site or some kind of a score of visitors' appreciation of what they have experienced. Similarly, paintings, crafts, photographs, poems, stories and songs can be seen, read or performed and numbers of participants counted, but their ultimate value and impact is more difficult to measure.

There are several examples from the UK where groups of people have come together to form 'Friends of meadows' groups, and are prepared to commit time and energy to fundraising and activities to raise awareness of the value of such habitats (see Case Study 3.2).

How to investigate the history of a floodplain meadow

Exploration of historical archives and archaeological investigations can both provide useful information about the longevity and past management of floodplain meadows. Interesting in its own right, this information can also be used to shape current and future management practices that might maintain and improve species-richness or to locate suitable sites for restoration projects.

1. Delve into the archives

There are many archives that can be explored for evidence, although these will vary depending on ownership history and location. Suggestions of where to look for particular information are given in Table 3.2.

Other general sources of information include:

- County Historic Records centres;
- *Maps for Family and Local History* by G. Beech and R. Mitchell (The National Archive 2004);
- *The Landscape of Place-names* by M. Gelling and A. Cole (Shaun Tyas Publishing 2000);
- The English Place-Name Society[6] has published detailed gazetteers of the settlement, field and road names of many counties; and
- Victoria County History[7].

Meadow names

Various names are used for different types of meadow but all relate to some aspect of the management (Brian 1994):

- ***Common meadow*** indicates use in severalty (with individuals from particular properties having the right to use specific hay allocations) during the hay-growing season with grazing in common (shared grazing) to the owners of the hay outside of the hay-making season.
- ***Dole meadow*** relates to strip ownership.
- ***Ings*** is a term for a meadow by the side of a river that floods in winter, used in Yorkshire, Cumbria and Lincolnshire (it is occasionally used more loosely for other hay meadows).
- ***Lammas meadow*** relates to the time of opening the meadow for grazing (see 'Lammas meadow' box).
- ***Mead*** is an archaic name for a meadow derived from the Old English *mǽd* and related to 'mow'.

Table 3.1 The wider benefits provided by floodplain meadows (adapted from Bullock *et al.* 2011).

Benefit	Examples	Outcome	More information
Agricultural benefits	Livestock: nutritious forage for cattle, sheep, etc.	Food (meat, milk), fibre (wool), possibly enhanced quality of meat and milk	Chapter 9
	Standing vegetation: biomass crops	Possibly fuel	Chapter 9
	Crops: pollination and pest control from invertebrates visiting species-rich grassland and then nearby farmed land	Food (crops)	
Cultural benefits	Environmental settings: valued species and habitats, agricultural heritage, archaeological heritage, grazing for rare livestock breeds, ecological knowledge, training areas	Physical and mental health and well-being, social cohesion, recreation and tourism, UK research base, environmental education	This chapter
	Spiritual enrichment, artistic inspiration and experiences of delight, wonder and sense of place		This chapter
Benefits to the environment	Climate regulation: sequestration and storage of carbon and other greenhouse gases	Reduction of climate stress	Chapter 5
	Water quantity: storage of floodwater and recharging of aquifers	Potable water, water for food production, flood protection – flood-risk management	Chapter 7
	Purification: reduced pollution through storage of pollutants, including nitrogen and phosphorus, and sediments	Clean air, clean water, clean soils	Chapter 5
	Wild species diversity: plant genetic diversity, seed for restoration projects	Genetic resources, bioprospecting, recreation and tourism, ecological knowledge	Chapter 8 Chapter 10

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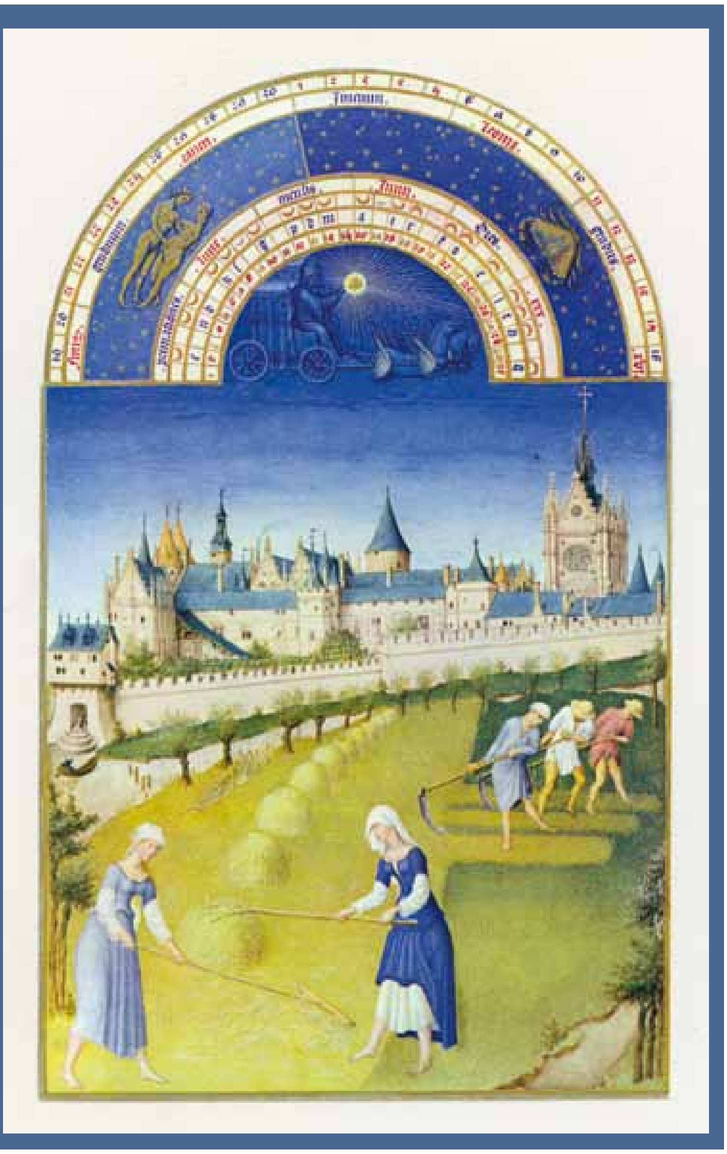
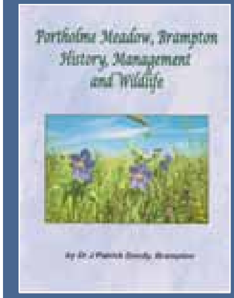
[6] http://www.nottingham.ac.uk/research/groups/epns/index.aspx

[7] http://www.victoriacountyhistory.ac.uk/about

Recreation and tourism benefits can be demonstrated by looking at the number of people visiting North Meadow each year. North Meadow hosts 80% of the UK population of snakeshead fritillaries, and the Natural England Reserve Managers actively promote the site to encourage visitors. In good years they have recorded nearly 300 visitors on average per day through April, the month that usually sees the highest number of visitors (Anita Barratt pers. comm.) © John Barratt

The rural idyll (not always such in reality of course) has been the subject of artists for hundreds of years including this one: 'June' Paul de Limbourg (1440). Digital image. © Mary Evans Picture Library. See www.hayinart.com for many more.





Portholme Meadow inspired Dr Pat Doody to find out more about its history and ecology, resulting in the publication of *Portholme Meadow, Brampton. History, Management and Wildlife*.

Snakeshead fritillaries (locally known as folfalars) found at Mottey Meadows in Staffordshire provided the inspiration for this mosaic snakeshead fritillary in the nearby village of Wheaton Aston. © John Rodwell

2. Archaeological investigations

Archaeological investigations can also be very informative, although they often require specialist skills and equipment. For example, archaeological investigations undertaken on marker stones at Lugg Meadow found small piles of stones underneath existing, dated, marker stones, suggesting that boundary markers were in use long before the current marker stones were put in place (Stone 1994). Pollen grains, seeds and invertebrate remains have provided evidence for hay making in the Oxford area from the Roman period (Lambrick and Robinson 1988).

Initial recording can be undertaken by site managers and non-specialists. This could include the mapping of visible features and searching the Historic Environment Record[8]. Subsequently, it is advisable to contact the Historic Environment and Archaeology team at the local council, where specialist advice can be sought (advice should also be sought for any groundworks as part of a management or restoration scheme to ensure there is no damage to existing archaeological features). For more detailed investigations including digging or the use of ground-penetrating radar, supervision by an archaeologist is required (for which funding may be needed).

Archaeological investigations may include:

- documentation of above-ground evidence such as marker stones, ditches and hedgerows;
- topographical survey of channels, ditches, ponds and other earthworks (some of which may have very early origins) to reveal information about past management practices;
- use of non-intrusive ground-penetrating radar and other geophysical techniques to see what lies underground that may merit further investigation;
- archaeological excavation where geophysical survey; indicates interesting features;
- analysis of un-decayed, waterlogged organic material, often extracted from old river channels and features such as pits and ditches. Pollen grains, seeds and insect remains (Robinson 2011) can reveal much about the land use and water levels at the time the ground became waterlogged (see Table 3.3); and
- radiocarbon dating of deposits.

Archaeological finds from the general area can also help identify previous agricultural practices. For example, scythe blades found at a number of Roman sites suggested extensive hay making had been carried out, as these tools are unlikely to have been suitable for anything else (Greig 1983).

Table 3.2 Where to look for historic information on floodplain meadows (adapted from Rodwell 2010[A]).

To understand …	Investigate …	Which may reveal …	From …
Present landscape	Ordnance Survey Explorer Maps at 1:25,000 scale – 2½ inches to the mile or 4 cm to 1 km. Aerial photos	Recent shape of the land, pattern of rivers and drains, presence of woodlands, dwellings and settlements, existing field boundaries (perhaps a remnant of older enclosures); place names that may reveal previous, perhaps ancient, land use	County Council Definitive Map Teams Ordnance Survey www.ordnancesurvey.co.uk Online satellite imagery e.g. Google Earth www.google.co.uk/intl/en_uk/earth/
Older landscape	Earlier Ordnance Survey maps e.g. The Godfrey Edition. 1:2,500 scale or 25 inches to the mile or the first 1:10,000 or 6 inches to the mile edition, completed in the mid to late 19th century	Earlier landscapes and how rivers and their floodplains have changed over time	These can be bought on line from sites such as: www.oldmap.co.uk/maps.php www.oldmapsonline.org/about/ www.old-maps.co.uk/ www.alangodfreymaps.co.uk/ and may be found in the local library or bookshop
Past land-use and ownership	The Tithe Awards (resulting from the 1836 Tithe Commutation Act) including the earliest large-scale maps for most of the parishes of England and Wales together with lists of landowners and tenants for all the enclosures	Ownership information, an indication of whether fields were under arable or grass (though not whether meadow); sometimes also show field names of the time	Local archives (e.g. County Historic Record Centres) National Archive at Kew, London www.nationalarchives.gov.uk/ Local museums (for artefacts)
Changing patterns of agricultural land use	Annual Parish Agricultural Returns from 1885 onwards	An overview of the pattern of farming across England and Wales on a parish scale	Parish archives. County Historic Record Centres National Archive at Kew, London www.nationalarchives.gov.uk/
Snapshot of Second World War land use	The MAFF National Farm Survey 1940–43 which included questionnaire responses and maps from every farm in the country	Details of the extent of meadow and pasture, arable crops, livestock and land condition	National Archive at Kew, London www.nationalarchives.gov.uk/
Landscape ownership and history	Manorial or Estate records and maps, Charters (written documents given as evidence of status, disputes, agreement, transfer or contract). Cathedral/church archives if relevant	Descriptions and sometimes maps of land holdings, locations and boundaries, land use. May include references to local landscape, place names, and the local economy	Estate records, parish archives, County Historic Record centres, National Archive at Kew, London www.nationalarchives.gov.uk/ Cathedral archives
People and their occupations	UK Census Returns every decade since 1801 (except 1941)	Information about the populations of settlements, dwellings and maybe occupations related to floodplain use	UK Census Online www.ukcensusonline.com National Archive at Kew, London www.nationalarchives.gov.uk/

[A] http://www.floodplainmeadows.org.uk/sites/www.floodplainmeadows.org.uk/files/files/FPMP%20Unearthing%20the%20past.pdf

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[8] http://www.heritagegateway.org.uk/Gateway/CHR/

Table 3.3 Un-decayed biological material that reveals much about past management and land use (summarised from Robinson 2011).

Type of material	Information provided
Pollen	Gives a broad picture of the vegetation in an area. Although it can be difficult to differentiate individual species, a grassland flora can readily be distinguished from a woodland flora
Seeds	Derived from a smaller catchment than pollen, but can often be identified to species level (except grasses)
Insect remains (particularly beetles)	Different species give an indication of the vegetation present at the time e.g. scarabaeid dung beetles suggest heavily grazed pasture while a high proportion of legume-feeding weevils indicates meadowland
Mollusc remains	Assemblages of snails typical of damp grassland indicate traditionally managed meadows

CASE STUDY 3.1
Strips, parcels and stones at Lugg Meadow, Herefordshire

The c. 1840 Tithe map shows Lugg Meadow divided into 133 different strips and parcels, each individually owned. The shape (i.e. strip or parcel) tended to be linked to past ownership. Strips were usually held by copyhold lease (i.e. by tenants of the Lord of the Manor), while parcels were part of whole farm leases, the latter being linked to the Church. On the area which is now the Lower Lugg Meadow, there were also two blocks of 'changeable' strips where ownership or tenancy changed each year.

Many of the strips or parcels are still individually named. The names the Five Rodds and Three Days Math both relate to the size of the parcel (the latter is what a man could mow in three days). Other names include the Swillow Swath and Shooters Hail. They are also still marked with over 100 stones (see Figure 3.2).

Figure 3.2 Some of the stones at Lugg Meadow have initials and a date on them; for example "CB 1833" marks each of the set of stones erected by Charles Bulmer of the cider-making family on the six strips he purchased in 1833. These strips had originally been charity land given to "support ten poor maids" (from Brian and Thomson 2002).

CASE STUDY 3.2
The Friends of Mottey Meadows, Staffordshire

The Friends of Mottey Meadows was set up in 2009 as a support group for Mottey Meadows National Nature Reserve, which is managed by Natural England. Following a public meeting, a committee of three was elected; today the group has 83 members, many of whom are actively involved.

The aim of the Friends of Mottey Meadows is to support the staff employed by Natural England in promoting and developing Mottey Meadows National Nature Reserve. Since 2009, it has been involved in a huge variety of fundraising events, practical volunteer days, butterfly surveys and public events on the meadows themselves. Every year on the third weekend of June, Natural England and the Friends of Mottey Meadows together run an annual Hay Making Festival. This public open day is free to all and involves wildflower walks, tractor rides, kids' activities, wildlife displays, arts and crafts, hot food and much more. Members of the Friends group help with stalls, refreshments, photography and organisation.

The Friends of Mottey Meadows have raised over £5,000 by hosting fundraising events including quizzes, race nights, treasure hunts, antiques road shows, and applying for small grants. These funds are spent on helping Natural England manage Mottey Meadows. To date the Friends have provided notice boards, signs, banners, gates and bridges and are still raising funds to pay for new hedges, fencing and machinery.

There are many other 'Friends' groups associated with floodplain meadows who are actively involved in site management, organising events and fundraising, including: The Bishops Meadow Trust[9] *(Bishops Meadow, Farnham, Surrey), The Cricklade Manorial Court*[10]*(North Meadow, Wiltshire), The Friends of Avon Meadows*[11] *(Avon Meadows, Pershore, Worcestershire), and the Friends of Rawcliffe Meadows*[12] *(Rawcliffe Meadows, York, Yorkshire).*

The Mottey Meadows Hay Festival is particularly targeted at the community of the nearby village of Wheaton Aston, and the numbers of people attending have risen over the years from 150 to 600. www.friendsofmotteymeadows.org.uk
© Mel Brown

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[9] http://bishopsmeadowtrust.org/
[10] http://www.crickladeinbloom.co.uk/fritillary_watch.html
[11] http://foam.btck.co.uk/
[12] https://rawcliffemeadows.wordpress.com/

CASE STUDY 3.3
A history of the Oxford Meads, Oxfordshire

The first historical references concerning the Oxford Meads date from the Anglo-Saxon period, when it is presumed that 'West' and 'Oxhey'[13] Meads, Yarnton, Wolvercote Lot Meadow and 'Picksey'[14] Mead '(McDonald 2007a) were set aside for hay.

The **Domesday Book** (1086) provides firm evidence of the existence of the Oxford Meadows and by 1142 references to Picksey Mead can be found; it was given to Godstow Nunnery at this time with five shillings of the endowment to be used for it to be mown on the Nativity of St John Day (24 June).

During the **13th century**, on Picksey Mead, rights to a customary acre were "vested in the ownership of a small cherry wood ball. Each owner of a ball would receive one customary acre every time it was drawn so that each farmer had the chance of getting some good hay and some poor hay each year. The number of times the balls were drawn was different according to the amount of meadowland available" (McDonald 2007a). The custom was to cut all the strips of hay in each mead in one day, beginning the first Monday after old St Peters Day (29 June).

The meadows survived enclosure in the **15th and 16th centuries** and continued to be managed in the same way. Mere stones were used to identify the position of different lots and as the local population grew in size, the customary acres were divided into smaller areas. During the **19th century,** as subsistence farming declined, rural workers moved into towns leaving no-one behind to gather the hay-crop, so landowners imported large numbers of labourers from outside the village. In Yarnton, this led to bad behaviour and drunkenness and, in 1817, the system was changed to enable local people to cut the hay over three days rather than one.

During the 20th century, with the reduction in the number of farmers wanting the hay, the lots for the year were auctioned to people from outside of the village. In 1958, when six acres of Picksey Mead were lost to the Oxford bypass, the remainder of the meadow was re-divided into 26 smaller lots. Soon after, the traditional management pattern of allocating hay as lots on this site was stopped altogether and management was undertaken by a single contractor.

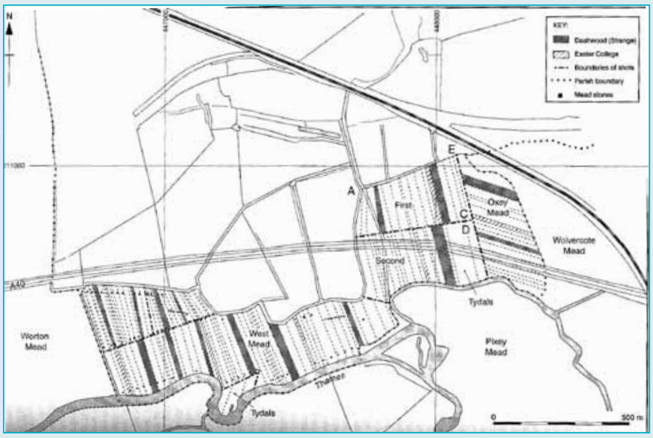

Figure 3.3 From at least the 9th century, the meads were divided into unenclosed strips (Hey 2004).

In the **21st century,** the tenancy was taken over by a multinational organisation (FAI Farms). The meads are managed mechanically, with the intention that traditional hay cutting in late June/early July and aftermath grazing by cattle followed by sheep will be reinstated once fences have been repaired. In the meantime, electric fencing allows aftermath grazing by sheep. Stocking levels are greater than in the past but the period of grazing is reduced *pro rata*.

Mere stones at Yarnton Mead. © Alison McDonald

CASE STUDY 3.4
North Meadow, Wiltshire: marker stones – the designation of floodplain-meadow features

Natural England owns North Meadow SSSI, which also forms part of the Clattinger Farm and North Meadow Special Area for Conservation, designated for its lowland meadow plant community. North Meadow has an ancient Lammas meadow management regime. The land is owned by Natural England. The grazing rights are held in common for the inhabitants of Cricklade from 12 August to 12 February each year. Documentary evidence from 1588 indicates that the management pattern then referred to was already well-established and may date back to the early medieval period (Whitehead 1982).

Features of historic interest are still present, including boundary stones indicating the allocation of hay strips to members of the parish around Cricklade.

The reserve managers wished to explore the value of these marker stones and establish whether they could be listed to provide them with a degree of statutory protection. A visit was made by the local County Archaeologist and it was agreed that the stones should be considered for listing as 'Buildings of Special, Architectural or Historic Interest' to reflect their special interest

[13] Now known as Oxey Mead
[14] Now known as Pixey Mead

A boundary stone indicating the ownership of John Boot (JB), North Meadow. It is one of the stones designated as a 'building of special architectural or historic interest'. © Emma Rothero

and national importance. The Secretary of State confirmed the designation in 1986 (see Figure 3.4). Historic features can also be listed on the local Historic Environment Record. This should result in them being considered in management/planning policies, but does not provide statutory protection.

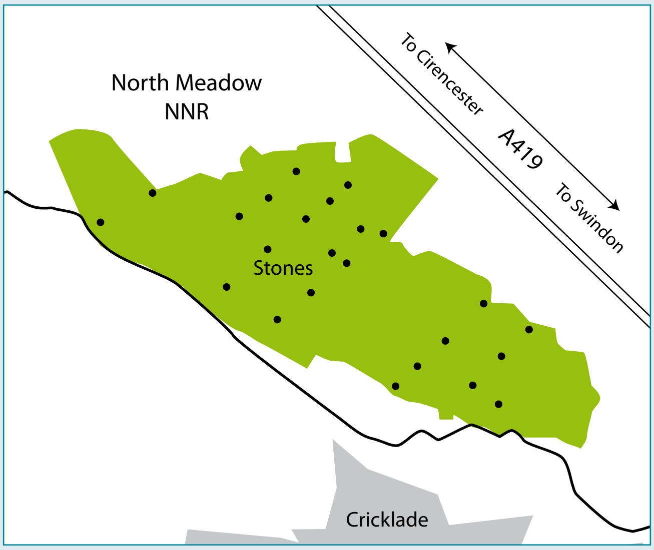

Figure 3.4 The map indicating the location of those stones included as part of the designation as a 'building of special architectural or historic interest' at North Meadow. The stones that are listed are those that were shown on the OS map.

CASE STUDY 3.5
Portholme Meadow, Cambridgeshire: an internationally important site for wildlife managed traditionally by auctioning hay lots and aftermath grazing

Portholme Meadow is designated as a Special Area for Conservation (SAC) for its Burnet floodplain meadow (MG4) plant community. It has been managed in the same way since at least 1772, and likely long before then. Lots (see maps in Figure 3.1.) are marked out today by mowing roadways in the hay before the annual auction, accurate through use of GPS and concrete slabs. Historically this was done by lining up local landmarks such as church spires and depressions in the ground to de-mark the lot allocations.

Today the hay and grazing for Portholme Meadow are sold at auction and the only appointee is the farmer, currently John Sewell (pictured), who marks out the roadways. © Pat Doody

The hay strips and aftermath grazing are sold each year at auction in mid June, by Brown and Co. with Alexanders (Huntingdon) who are responsible for ensuring that the hay is sold in an appropriate and open manner. Historical conditions are still adhered to including that hay is to be cut and removed by 8 August, and grazing rights are sold according to a set number of stock:

- 281 cattle from 1 September to 20 November;
- 334 sheep from 21 November to 28 February.

There are restrictions set by Natural England including no fertilisers or herbicides, and the hay is not to be cut these days before 15 June. There is some indication that the newer machines cut faster and closer to the ground and may be deleterious to elements of the breeding bird fauna.

Hay values from Portholme vary from year to year depending on weather conditions, but the highest value hay tends to come from the more species-rich areas.

Case Study extracted from Doody (2007).

Many thanks to additional contributors Anita Barratt, Mel Brown, Sue Holland, Alison McDonald, Rob McInnes, George Peterken, John Rodwell, Nicky Smith and Wes Weate.

Chapter 4
Conservation

Emma Rothero and Sophie Lake

This chapter considers why so many floodplain meadows have been lost or degraded, describes the current extent of key vegetation communities and their conservation status and discusses current and future threats.

The decline of floodplain meadows

The distribution and extent of floodplain meadows in the past is not really known, but they are thought to have been widespread wherever suitable substrate, topography, hydrological regime and land-use practices coincided (Jefferson 1997). For example, Rackham (1986) suggests that by the 13th century, most floodplains (including those of small streams) were managed as meadows. These fertile meadows were of great agricultural value to rural communities (see Chapter 3) and their wildlife interest was maintained as a by-product of traditional agricultural practices. However, agricultural intensification since the mid 20th century led to rapid (but unquantified) losses of floodplain meadows, whose flat terrain and fertile soils made them more likely to be agriculturally intensified than other lowland grassland types (Rodwell *et al*. 2007). This decline was exacerbated by losses through sand and gravel extraction, urban and industrial development (Jefferson and Pinches 2011) and hydrological changes to river floodplains. Table 4.1 summarises the main causes of the loss and degradation of floodplain meadows. Declines continued throughout the 1980s and 1990s, but are thought to have slowed considerably during the 2000s[15].

Floodplain meadows today

Although the reinstatement of appropriate management and the re-creation of floodplain-meadow communities through re-seeding have helped to arrest recent declines, floodplain meadow remains one of the rarest lowland

Table 4.1 Reasons for the changes in area and quality of floodplain meadows over the last century (adapted from Jefferson and Pinches 2011).

Key issue	Impact
A. Agricultural changes	
1. Conversion to intensively managed grassland by ploughing and re-seeding with high yielding grasses/legumes or through the use of inorganic fertilisers	Loss of floodplain-meadow species (including breeding/wintering birds)
2. Conversion to arable	Loss of floodplain meadows
3. Changes in the grazing regime including cessation of aftermath grazing, or use as pasture	Conversion to more species-poor vegetation
4. Changes to hay-cutting practices, including later cutting or conversion to silage making	
B. Hydrological changes and soil compaction	
5. Water abstraction, mineral extraction, and flood alleviation lowering the water table	Conversion to drier grassland communities, impacts on breeding waders and invertebrates
6. River engineering preventing seasonal flooding	Reduction in nutrients (increasing the likelihood of the use of artificial fertilisers)
7. Raised spring/summer water levels e.g. through artificially raised river levels or soil compaction	Conversion to wetter grassland/swamp communities as a result of waterlogging
8. Cessation of ditch/surface drain maintenance	
C. Development	
9. Mineral extraction or urban development	Loss /degradation of floodplain meadows
D. Nutrient enrichment	
10. Atmospheric deposition of nitrogen, excessive deposition of phosphorus and nitrogen from floodwater	Degradation of floodplain-meadow plant diversity
E. Climate change	
11. Changes in temperature and rainfall leading to shifts in species distributions	Changes in species composition and potentially plant community type
12. Alteration of hydrological status	See impacts under sections B and D
13. Change in agricultural practices	See impacts under section A

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[15] http://jncc.defra.gov.uk/pdf/Article17Consult_20131010/H6510_UK.pdf

The use of artificial fertilisers, the application of herbicides and the prevalence of silage making have led to the degradation of many remaining floodplain meadows.
© Durwyn Liley/Sophie Lake

grassland types in the UK. Only around 2,980 ha are thought to remain in England and Wales[16]. They are largely confined to the English lowlands, with just a few hectares in Wales. Key areas include the floodplains of the Thames, Severn-Trent, Yorkshire Ouse and Derwent (Jefferson 1997), the Hampshire Avon, Itchen and Test (see Figure 4.1).

Conservation status

In an effort to remove or reduce these pressures, most remaining floodplain meadows have been designated as SSSIs (see 'Designations' box opposite) (Holmes *et al.* 2005). For example, by 2011, about 69% of the resource of Burnet floodplain meadow (MG4) and 84% of Kingcup-carnation sedge meadow (MG8) was within SSSIs. There are currently nine SSSIs that support both communities, while 104 just have Kingcup-carnation sedge meadow (MG8) and 84 just have Burnet floodplain meadow (MG4). The revised lowland grassland SSSI guidelines (Jefferson *et al.* 2014) lists both communities as nationally rare grassland types of high botanical value; sites supporting 0.5 ha or more would qualify as SSSIs.

Some 1,420 ha of floodplain meadow also fall within five SACs (see 'Designations' box) designated for the presence of the Annex I habitat Lowland Hay Meadows (*Alopecurus pratensis-Sanguisorba officinalis*), which the UK has interpreted as corresponding to the Burnet floodplain meadow (MG4) NVC community. Kingcup-carnation sedge meadow (MG8) was not considered in the UK to fall within the Annex I habitat Lowland Hay Meadows (Rodwell *et al.* 2007). However, some floodplain meadows supporting this plant community are designated as Special Protection Areas under the Birds Directive for their populations of wintering or breeding birds. Together with Burnet floodplain meadow (MG4), Kingcup-carnation sedge meadow (MG8) is also included within the Priority Habitat Lowland Meadows (see 'Designations' box).

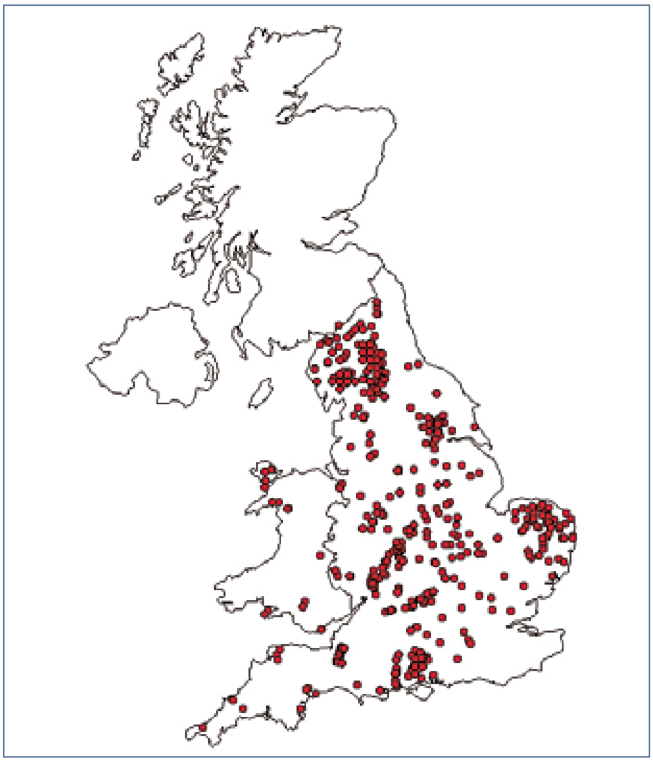
Although Local Sites (see 'Designations' box) are not legally protected, the importance of their role in the ecological networks that are needed to halt the decline of biodiversity is recognised in the National Planning Policy Framework[17] (which sets out guidance on planning policy in England and how it should be applied). Given the relatively high proportion of floodplain meadows designated as SSSI, there are fewer Local Sites, and some of these are under consideration for SSSI status.

Non-designated sites receive a measure of protection through Environmental Impact Assessment[18], a formal procedure to assess the potential environmental impact of certain changes to land use before agricultural works are allowed to proceed. However, it is considered to have been ineffective in its role of grassland protection in England[19].

Non-governmental organisations such as the Wildlife Trusts, Plantlife and the RSPB contribute to the conservation of floodplain meadows through the acquisition of sites for nature reserves, policy advocacy, research and monitoring. The Floodplain Meadows Partnership has been formed to help co-ordinate the conservation of floodplain meadows (see box).

Given the particularly sensitive nature of this vegetation to even small changes in hydrology and management, all remaining sites, designated or not, should be considered as important, and protected and managed in a sympathetic way.

Figure 4.1 Distribution of species-rich floodplain meadows in England and Wales. The map indicates known sites containing Burnet floodplain meadow (MG4), Kingcup-carnation sedge meadow (MG8), Sedge lawn (MG14), Cuckooflower grassland (MG15p) and Ryegrass pasture Meadowsweet sub-community (MG6d)[20].



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16 http://www.floodplainmeadows.org.uk/about-meadows/wildlife/plant-communities

17 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/6077/2116950.pdf

18 Environmental Impact Assessment (Agriculture) (England) (No. 2) Regulations 2006 see http://publications.naturalengland.org.uk/publication/4038539

19 http://jncc.defra.gov.uk/pdf/Article17Consult_20131010/H6510_ENGLAND.pdf

20 The NVC codes referred to are explained more fully in Chapter 8.

Designations

SSSIs – Sites of Special Scientific Interest are sites of particular wildlife or geological interest which are legally protected through the Wildlife and Countryside Act 1981 (as amended). They are notified by Natural England, who ensure that they are managed appropriately and monitor their condition. See: https://www.gov.uk/guidance/protected-areas-sites-of-special-scientific-interest

SACs – Special Areas of Conservation are sites designated under the European Habitats Directive for the presence of habitats listed on Annex I of the Directive, and form part of a network of protected sites of international importance known as Natura 2000. See: http://jncc.defra.gov.uk/page-23

SPAs – Special Protection Areas are sites designated under the European Birds Directive for their international importance for birds, and also form part of the Natura 2000 network. See: http://jncc.defra.gov.uk/page-162

NNRs – National Nature Reserves are nationally important nature reserves containing examples of the important habitats, species and geology. In many cases, they are owned and managed by conservation organisations such as Natural England, National Trust, Forestry Commission, RSPB, Wildlife Trusts and local authorities. See: https://www.gov.uk/government/collections/national-nature-reserves-in-england and http://www.snh.gov.uk/protecting-scotlands-nature/protected-areas/national-designations/nnr/

Priority Habitats are those listed in Section 41 (England) and Section 42 (Wales) of the Natural Environment and Rural Communities (NERC) Act 2006. Previously known as Biodiversity Action Plan Habitats, these are habitats considered to be of principal importance for the purpose of conserving biodiversity. See: http://jncc.defra.gov.uk/page-5705

Local Sites (e.g. County Wildlife Sites, Sites of Nature Conservation Importance and similar) are sites of conservation interest at the local level. Although not legally protected, their importance is recognised by local authorities for example when considering planning applications. See: http://webarchive.nationalarchives.gov.uk/20130402151656/http://archive.defra.gov.uk/rural/documents/protected/localsites.pdf%20

MAGIC is a useful online interactive mapping facility which provides geographic information on site designations with links to individual site details: http://www.magic.gov.uk/

A co-ordinated approach to conservation

The Floodplain Meadows Partnership, established in 2007, comprises the major conservation, research and educational organisations interested in floodplain meadows (Natural England, Environment Agency, the Wildlife Trusts, the RSPB, the Centre for Ecology and Hydrology, the Open University, the National Trust, the Field Studies Council and People Need Nature). The partnership undertakes research, collates data on the distribution of the habitat, monitors its status and shares findings with interested stakeholders, helping to raise the profile of the importance and value of the habitat. See www.floodplainmeadows.org.uk/

Floodplain Meadows Partnership

Agri-environment schemes

Appropriate management is supported on many floodplain meadows through agri-environment schemes. These provide area-based payments to farmers and land managers to farm in a way that supports biodiversity, enhances the landscape, and improves the quality of water, air and soil.

Under the Environmental Stewardship scheme, funding can be received for a wide range of options, many of which can apply to floodplain meadows. Of particular relevance are the more restricted Higher Level Scheme (HLS) options for the creation, enhancement or maintenance of species-rich grassland and for grassland suitable for waders, with supplements for hay cutting and for the use of native livestock breeds at risk.

Agreements set up under the Higher Level Stewardship (HLS) scheme may run until 2025, while agreements under Countryside Stewardship start in 2016 and will have very similar options to HLS for the maintenance, restoration and creation of species-rich grasslands plus management of grassland for target features. There will also be a similar range of supplements relating to grassland as per the existing scheme except there will no longer be a supplement for difficult sites.

Many floodplain meadows are managed under agri-environment agreements aimed at promoting effective environmental management, which can include the maintenance, restoration or creation of floodplain meadows. Supplements for hay cutting, raised water levels and cattle grazing are also available.

Unfortunately, statutory designation and management under agri-environment schemes has not always proved sufficient to prevent the degradation of floodplain meadows, and estimates suggest that the ecological structure and functioning of about 45% of sites designated for Burnet floodplain meadow (MG4) are in poor condition[21] although some are considered to be recovering. However, the shift from 'unfavourable' to 'unfavourable recovering' is often made on the basis that a site has a new management agreement (Mountford *et al*. 2013); as yet there seems to be little detailed monitoring evidence to determine what proportion of sites is actually improving. The status of undesignated sites is likely to be worse (Hewins *et al*. 2005).

[21] http://jncc.defra.gov.uk/pdf/Article17Consult_20131010/H6510_UK.pdf

Increases in species-poor waterlogging-tolerant communities observed in recent years are associated with the wet summers of 2007, 2008 and 2012. Most changes are in the floristic composition within a community rather than shifts between communities, for example from the Typical Burnet floodplain meadow (MG4b) sub-community to the Creeping bent sub-community (MG4d) as seen at North Meadow, Cricklade. However, shifts between communities can also occur, for example from Burnet floodplain meadow (MG4) to Foxtail grassland (MG7d) (Gowing *et al*. 2005; Wallace and Prosser 2004; Wallace and Gowing 2012), from Kingcup-carnation sedge meadow (MG8) to Sedge lawn (MG14) or from Foxtail grassland (MG7d) to Foxtail plash (MG13) (Wallace and Prosser 2007) (see Chapter 8 and Appendix for community descriptions).

Active management to increase the soil wetness of sites for specific conservation objectives (e.g. to increase suitability for breeding waders) has in some cases contributed to a decline in the plant diversity of species-rich meadows for the same reason. Changes in agricultural practices are also impacting on floodplain-meadow plant communities. In particular, later hay-cutting times can impact negatively on species diversity, and abandonment is an increasing problem.

The future

Most remaining floodplain meadows are under 10 ha and as such are very vulnerable to changes in management in the wider floodplain (including hydrological changes), stochastic events (e.g. prolonged flooding) and on-site management issues. The rate of decline may have slowed considerably, probably due to the success of conservation programmes, but a new threat, atmospheric nitrogen deposition, is considered to be exceeding the critical load, beyond which deleterious changes will occur across much of the habitat's range. This is an ongoing threat, and one that is particularly hard to tackle.

The potential impacts of climate change are varied (Natural England and RSPB 2014). Changes in rainfall patterns may lead to increased frequency and duration of flooding, which could result in a shift towards swamp and inundation grassland communities, particularly if flooding occurs more often in spring and summer. Increased levels of soil phosphorus as a result of more frequent flooding are also likely to affect plant communities adversely (e.g. Gowing 2008).

Floodplain meadows are also sensitive to reductions in summer rainfall, which puts stress on wet meadow communities in late summer and autumn and may lead to changes towards drier communities (Carey 2013). Systems relying predominantly on local rainfall rather than river water or groundwater will be most affected. Hotter summers may change plant phenology, with earlier flowering and seed-setting times. Changes in the economics of livestock grazing systems due to climate change may also have a significant impact, leading to abandonment or increased intensification. Watercourses may carry higher nitrogen loads (due to increased mineralisation under increased temperatures and reduced water flow) which would promote the growth of more competitive species to the detriment of species diversity.

Land purchase by conservation organisations is a well-established method to protect important sites. Recent years have seen novel approaches to facilitating this, including through the use of social investments from funding organisations (see Case Study 4.2).

Current pressures on floodplain meadows are similar to those that resulted in losses throughout the 20th century: addition of artificial fertilisers, cessation of aftermath grazing and/or cutting, adverse changes in hydrology including change in flooding regimes and drainage maintenance, and nutrient enrichment from atmospheric nitrogen deposition (Jefferson and Pinches 2011; Bullock *et al*. 2011).

Challenges for the future

- Increase the area of floodplain meadows by restoring semi-improved sites and creating new floodplain meadows on improved grassland and arable land. Will help society adapt to the effects of climate change.
- Respond to variation in seasonal growing conditions and changes in flowering dates through varying the timing of hay cuts and the timing, duration and extent of aftermath grazing.
- Maintain or restore water-level management including ditch networks and in-field gutters.
- Increase structural heterogeneity by varying the type and timing of management interventions.
- Monitor invasive non-native species and introduce management measures to minimise colonisation of undesirable species.
- Raise awareness of the value of floodplain meadows to society, including flood and carbon storage, supporting pollinating insects, storing sediment and processing nutrients.

(See also Natural England and RSPB 2014.)

Traditional British white cattle, grazing in the Avon Valley, Hampshire. A decline in livestock farming on floodplain meadows is resulting in the abandonment of grazing in some cases (although the high productivity of floodplain meadows means they are less likely to be abandoned than some less productive semi-natural grasslands). Changes in livestock type (e.g. from cattle to horse grazing) are resulting in a change from traditional management but, in many areas of the country, floodplain meadows are still seen as a source of high quality hay. © Ann Skinner

European context

The scarcity of surviving floodplain meadows in England and Wales is mirrored across continental Europe. At least fragmentary stands of species-rich floodplain meadows remain widely distributed across Europe.

Well-documented examples are known from the Netherlands, northern France, northern and western Germany and Belgium, with other published records from Italy, Austria, Poland, the Czech Republic, Hungary, Croatia, Romania, Bulgaria and the Baltic states. In general, the *Alopecurion* group of plant communities of which Burnet floodplain meadow (MG4) is a part, tends to have a more westerly concentration than does the wetter *Calthion* group which includes Kingcup-carnation sedge meadow (MG8) and Sedge lawn (MG14).

Species-rich floodplain meadows remain scarce across Europe with issues similar to those in the UK. Russia however may be a stronghold. Zalidovskie Luga Meadow, Kaluga National Park, is 1,000 ha. © Mike Dodd

The losses experienced in the UK are similar to those found across Europe. Krause *et al.* (2012) estimate that wet and species-rich meadows have declined by more than 80% on the floodplains of Northern Germany since the 1950s; whilst Soons *et al.* (2005) describe the almost complete disappearance of wet and moist grasslands over the past 100 years from riverine landscapes in the lowlands of the Netherlands. In Hungary, wet meadows have declined by over 65% in recent decades (Joyce and Wade 1998). A similar figure is given for Estonia (Kana *et al.* 2008) and of the surveyed areas of Estonian floodplain meadows, less than half are considered as being in satisfactory condition. *Alopecurion* grasslands are regarded as 'nationally threatened' in Italy, Bulgaria and Latvia (Rodwell *et al.* 2007).

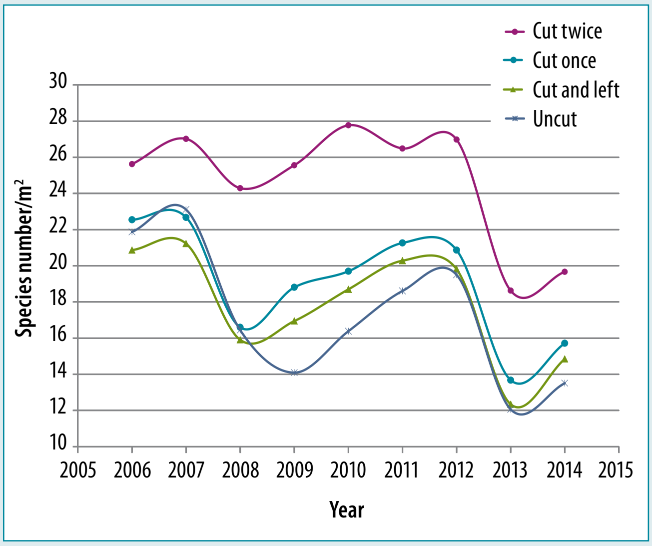
CASE STUDY 4.1
Extreme flooding and subsequent management of the species-rich plant community at North Meadow National Nature Reserve, Wiltshire

North Meadow, Cricklade is one of five sites in the UK designated as a SAC for its Lowland Hay Meadow plant community 6510 *Aloperucus pratensis-Sanguisorba officinalis*; which corresponds to Burnet floodplain meadow (MG4) in the National Vegetation Classification (Rodwell 1992). It is a National Nature Reserve, owned and managed by Natural England. Botanical, hydrological and soils monitoring have been undertaken at the site since 1998 by the Open University (Floodplain Meadows Partnership).

Recent years have seen an increase in the frequency of extreme floods. The impacts of increased severe flooding are dependent on the timing of flooding and subsequent site management. **Winter flooding**, as experienced in 2013/2014 when it was of longer duration than previously recorded at the site, may have limited impact provided the annual hay cut is taken the following summer to remove flood-borne nutrients. **Spring flooding** can have a direct impact on plant growth, resulting in a decline in less flood-tolerant species and a shift to a more species-poor vegetation community. **Summer flooding** has had the biggest impact on North Meadow, largely because it prevented timely hay making.

The annual pattern of hay cutting and grazing post-flooding has a critical role to play in maintaining species diversity. Figure 4.2 demonstrates that where it is not possible to take a summer hay cut, species-richness declines more than where it is possible to

Figure 4.2 Change in species-richness at North Meadow related to hay cutting in 2007 and 2008. Data expressed as % change on pre-flood (2006) species-richness. Distinction is made between those plots that were cut in 2008 and had the hay removed (cut once), plots that were cut in both years, and those plots that were cut but the hay was not removed (cut and left). Uncut refers to plots that were not cut in either 2007 or 2008.



take a prompt cut. Hay making removes nutrients brought in by floods and therefore subdues larger, more vigorous species. If adequate aftermath grazing is not possible, a second cut in late August for up to three years post-flooding may also help reduce soil fertility.

Appropriate management is critical in restoring species diversity: the plant community can tolerate more prolonged flood events if management is flexible enough to mitigate impacts, and provided summer flooding does not prevent management from taking place.

On-site water-level management is also critical to avoid the prolonged periods of inundation such as those experienced in 2012/2013. At North Meadow some of the site could not be cut in 2012 because machinery could not get to parts that were dry, as other areas of the meadow were flooded.

Following the summer flood of 2012, the most species-rich Cock's-foot sub-community (MG4a) of Burnet floodplain meadow (MG4) (see Chapter 8) has been all but lost due to the lack of recovery of many of its diagnostic species including cock's-foot, crested dog's-tail, yellow oat-grass and oxeye daisy (Wallace and Prosser 2013).

After a severe summer flood, seven to ten years may be a realistic time for full species recovery. Currently at North Meadow, periods of just five years between recent floods have not allowed species-rich communities to recover fully.

CASE STUDY 4.2
Use of social investments to buy land for nature conservation

Some major funding organisations now consider social investment to be a useful mechanism in helping the UK's fragmented landscapes. The Esmée Fairbairn Foundation (EFF) has a facility available called the Land Purchase Fund, through which they work with three major conservation organisations (the RSPB, the Wildlife Trusts and the Woodland Trust) to purchase sites of strategic conservation importance. EFF purchase the land and provide a two-year window for the organisation to fundraise in order to buy the land from them. To date, they have made 11 land purchases totalling over £8 million with six successfully sold on to the applicant organisation and secured for conservation so far.

Worcestershire Wildlife Trust[22] (WWT) is an example of an organisation participating in this scheme. WWT wanted to buy Hollybed Farm Meadows (16 ha) when they came up for auction in 2012. WWT approached EFF about the proposal and EFF agreed to purchase the land, leasing the land to WWT and giving it a two-year window in which to raise the funds to buy the land from EFF.

Since drawing up the agreement with EFF in 2012, WWT has been managing the site (which includes ten meadows, an orchard and a small wet woodland) as a nature reserve. Management has included spreading seed taken from Far Starling Bank SSSI (which forms part of the site) across the rest of the site in order to help increase the spread of plants throughout the individual fields.

WWT needed to raise more than £382,000 to purchase and manage the land, and successfully achieved this within the timescale. Contributions include a legacy gift to be used for the benefit of the wildlife of Worcestershire, a membership appeal raising £105,000, a grant of £65,900 from the Heritage Lottery Fund[23] and a donation of £50,000 from Severn Waste Services[24] through the Landfill Communities Fund.

Volunteers strewing green hay at Hollybed Farm Meadows. © Chris Ellory

Many thanks to additional contributors Jenny Dadd, James Hitchcock, Kate Thomas and Hilary Wallace.

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[22] http://www.worcswildlifetrust.co.uk/
[23] www.hlf.org.uk/
[24] www.severnwaste.com/landfill-communities-fund/

Chapter 5
Soils

David Gowing

Understanding the soil is key to managing and conserving a floodplain meadow. This chapter focuses on the physical properties of soil including soil profile, texture, structure and capacity for water retention. It explains why these are important when considering the management of floodplain meadows. For information on the chemical aspects such as pH and nutrients see Chapter 6.

Soil development

Soil is a collection of mineral particles, organic residues, air, water and living organisms. It is a complex material, so this chapter focuses on those issues that are of relevance to the management and restoration of floodplain meadows. Floodplain meadows predominantly occur on alluvial soils i.e. sediment that has been deposited by rivers during flood events. The size of the mineral particles deposited varies from coarse sands and gravels to fine silts and clays, depending on the speed of the water during the flood event. Knowing whether terrace deposits (i.e. sands and gravels) underlie a floodplain and then knowing the depth of alluvium (silts and clays) above them are two key pieces of information for floodplain-meadow management.

How to investigate soil

Some soil characteristics, such as the soil profile, texture and structure, can be explored through observation in the field. More detailed information about physical structure, for example on soil porosity or how water moves through the soil, requires laboratory analysis of soil samples or more complex field measurements. Different soil characteristics and ways to measure them are described here and summarised below.

Soil profile

The first step is to look at the soil profile, which shows the presence and depth of different horizons (see Table 5.1, 5.2 and Figure 5.1). This can be informative in terms of floodplain-meadow management. For example, the presence of terrace deposits in the 'C' horizon and a shallow alluvial layer in the 'B' horizon would indicate that the water table is likely to be responsive to changes in the water level of ditches and the river. A deep and friable 'A' horizon with plenty of humus suggests the site is likely to be suitable for a species-rich floodplain meadow. To determine the nature of the soil profile at a site, there are three approaches to consider: examining existing exposed profiles created through river bank collapse, using a soil auger, or a creating a soil pit. All three can be carried out by anyone with the appropriate equipment and the necessary permission. Local maps from the British Geological Survey are available to view online[25] and show the location of gravel deposits; these are also useful for starting to understand a site.

Texture

Texture refers to the size of the mineral particles in the soil (see Table 5.3 and Figure 5.2) and can be ascertained through touch. Knowing the texture of the soil makes it possible to make first approximations about how water will move through it (generally rapidly through sands and slowly through clays), how well it will bind and retain mineral nutrient (sands do this poorly, clays do it well) and how susceptible it is to compaction (silts are at particular risk).

Structure

Soil structure is more relevant to the management of a site than soil texture, and can be established through examination. Structure refers to the way soil particles aggregate together to form structural units or 'peds' (see Figure 5.3). In a poorly structured soil, fine particles may be aggregated into large uniform blocks through which the movement of water and air is limited. This is normally a result of compaction. However, processes such as root growth, the activity of soil animals and fungi, drying and wetting cycles and freeze/thaw cycles all create movement in the soil, which breaks up the blocks into smaller units. In a very well-structured soil, these units are as small as breadcrumbs and they act as the fundamental particles of the soil. A very well-structured clay soil can have discrete units the size of coarse sand grains and, as a result, the aeration and hydraulic properties of the soil will act in the same way as for a coarse sand.

A brief history of floodplain-meadow soils

Coarse sediments were widely deposited on floodplains following the end of the last Ice Age around 11,500 years ago. Melting snow fields and ice sheets created swollen rivers each spring that eroded upland areas and re-deposited the transported material onto lowland floodplains. The resultant layers of sand and gravel still underlie many floodplains and are often referred to as 'terrace' deposits. These terrace deposits play a pivotal role in the hydrology of floodplains, allowing water to flow freely through them. Estimates suggest that some floodplains have a greater volume of water travelling through subsurface gravels than in the river channel itself. As the winters warmed, the periods of meltwater spate declined in frequency and strength, and the speed of water crossing floodplains became slower. Slow-moving water drops its fine sediment and this forms the basis of alluvial soils. The depth of alluvial soil that has accumulated above terrace deposits on meadow sites can vary from just 15 cm to as much as three metres.

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[25] www.bgs.ac.uk/data/mapViewers/home.html

Table 5.1 Soil investigations.

Investigation	Method	Expert help or specialist equipment needed?	Interpretation
Soil profile	Examine existing exposure e.g. river bank	No	The thickness of the alluvium above any terrace deposit provides an indication of how easily water will move through the soil and thus how dependent the meadow is upon the water levels in surrounding watercourses
	Use soil auger	Augers available from specialist suppliers	
	Dig soil pit	No (permission needed if legally designated site)	
Texture	Observation, touch	No	Allows an estimate of the silt and clay content of the soil and thus its susceptibility to compaction
Structure	Observation	No	Gives an indication of how water will move through the soil and whether compaction has occurred in the past
Porosity	Collect an undisturbed sample and measure its soil-moisture-release characteristics	Send sample to soil-physics laboratory. Sampling ring required	Indicates pore size, which determines how well the soil drains and how liable it is to waterlogging
Water storage	Collect sample and measure specific yield	Send sample to soil-physics lab. Sampling ring required	Indicates how much water the soil can store, which is useful for estimating the flood storage potential. Determines how rapidly water tables will fluctuate, which influences the type of vegetation that will grow
Water flow	Measure hydraulic conductivity using the auger-hole method	Requires basic training, an auger, a baling can and a stopwatch	Determines the extent to which the water table in the meadow is affected by the water level in surrounding watercourses
Compaction	Dry a known volume of soil in an oven to ascertain dry bulk density	No	Indicates degree of compaction
	Dig a soil pit	No	Indicates degree of compaction

Table 5.2 The horizons of a classic soil profile.

Layer	Colour	Characteristics
'O' horizon	Dark brown–black	An accumulation of dead organic matter, usually absent in actively managed floodplain meadows
'A' horizon	Dark brown	Plentiful organic residues incorporated into mineral soil, biologically active
'B' horizon	Lighter in colour (on alluvial soils)	Organic content is reduced, some roots penetrate, but biological activity is lower
'C' horizon	Variable	Terrace deposits such as sands and gravels, or the incompletely weathered product of the underlying bedrock, such as clay

The soil profile can also be examined using a hand-held 50 mm auger. There are two types of auger: one looks like a giant corkscrew, the other like a bulb planter on a long rod. Both are used to extract a core of soil a few centimetres in diameter down to about two metres. As the soil is removed from the hole, it can be laid out sequentially to give a visible record of the profile (more information about how this soil sample was used is given in Chapter 10, Case Study 10.1). © Heather Procter

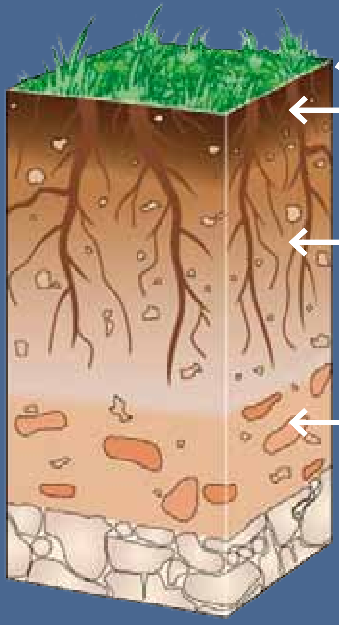
Organic matter and peat soils

The bulk of organic matter found in soils is dead plant tissue (fallen leaves and discarded roots) but the remains of soil animals, bacteria and fungi and the faeces of animals from tiny springtails to cattle all contribute. Flood-deposited debris (e.g. reeds and small woody debris) is a further source. Organic matter is important as a store of carbon and as a modifier of the soil's chemical and physical properties. Chemically it has the ability to bind nutrients and thus to increase the fertility of the soil. Physically it increases the stability of the structural units and makes the soil more resilient to compaction. Organic matter can be lost via oxidation whenever the soil is disturbed. Old grasslands that have not been ploughed for hundreds of years can therefore be a very important repository of carbon. Alluvial soils beneath meadows tend to be rich in carbon so carbon sequestration is a valuable benefit provided by the habitat.

Peat soils are predominantly composed of organic material and are formed under waterlogged conditions. Floodplains generally have mineral soils formed from alluvium (sediments that have been eroded, reshaped and re-deposited by water). However, where rivers have little gradient and the water tables stay high through the year, fibrous materials such as litter from sedges and reeds remain undecomposed and accumulate to form fen peat. Fen peat tends to have an open structure through which water can move as rapidly as through gravel, although this structure can be lost through oxidation, tillage or compaction. In a damaged peat soil the movement of water and air is impeded and, as for mineral soils, compaction should be avoided.

Understanding a soil profile

To get a full picture of the soil, especially with respect to its structure, a soil pit is required. This is a larger undertaking as the pit usually needs to be one metre square and over a metre deep, which might involve moving up to two tons of soil. Permission is required to make such an excavation on a floodplain, as it is potentially damaging to the hydrology and ecology and thus should only be considered where an important question needs to be addressed. The soil pit should be filled back in as soon as possible and the different horizons should be put back in the correct order.



'O' horizon is typically absent or very thin in grassland soils.

'A' horizon is rich in organic matter and well-structured, approximately 20 cm thick. Attention should be paid to maintaining its integrity by avoiding compaction.

'B' horizon is paler and usually formed of alluvium. It is less permeable and the ability of the soil profile to drain often depends on the thickness of this layer.

'C' horizon is composed of terrace deposit or parent rock. If it has high permeability it may dominate the lateral movement of water across the site.

Figure 5.1 A soil profile diagram showing the 'O', 'A', 'B' and 'C' horizons. © The Open University 2015

Soil profile through the bank of the River Churn (adjacent to North Meadow). River banks often provide the opportunity to see the thickness of the various layers and confirm the presence of terrace deposits. © Mike Dodd

Table 5.3 Soil particle size classification.

Particle size	Type
<0.002 mm	Clay
0.002–0.06 mm	Silt
>0.06 mm	Sand

Figure 5.2 It is rare for a soil to be composed of particles all of a uniform size and so most soils have a proportion of each and a three-axis plot is required to allocate a texture class. Where the three size classes are fairly evenly represented, then the term 'loam' is used to describe the soil.

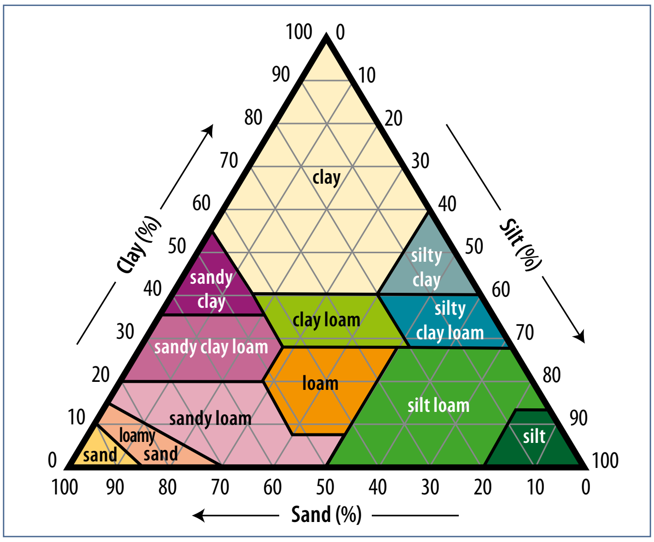
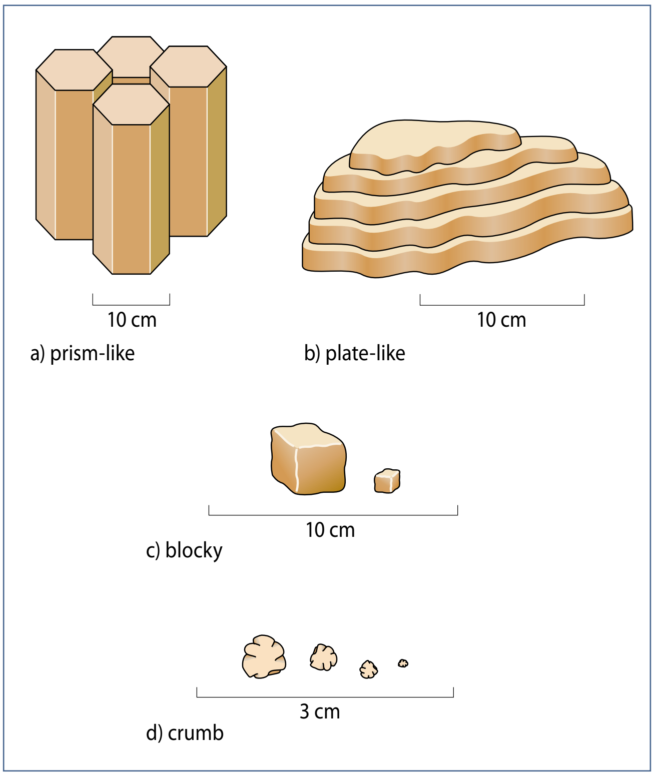


Figure 5.3 Schematic diagram of different types of ped, ranging from large (a) prism-like or (b) plate-like aggregates of poorly structured soil, to small (c) blocky or (d) crumb-shaped aggregates of well-structured soils. © The Open University 2015



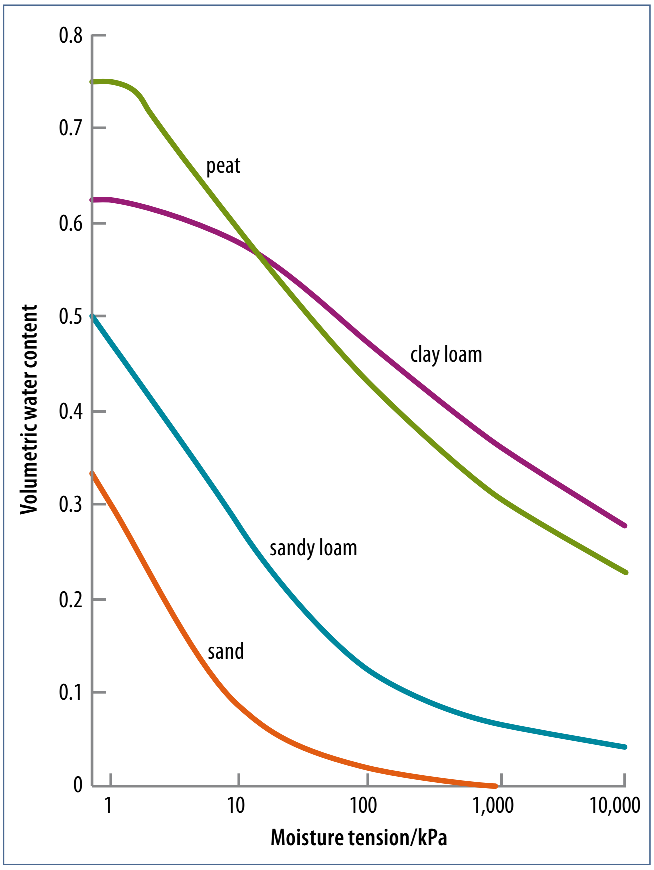
Structure is fragile and small structural units can be squashed back together through compaction by grazing animals and machinery on wet soils. Wet soils are particularly liable to compaction because they lack strength.

It is important to keep stock and machinery off the meadow when the soil is close to saturation. Once the structure has been lost through compaction, it can take decades to recover. Compaction leads to loss of species diversity and a shift away from characteristic floodplain-meadow plant communities. The loss of a hay crop or a few months' grazing is a price worth paying for protecting soil structure.

Water storage and movement in soils

The availability of water in soils and the ease with which it drains is important in terms of the plant communities supported (see Chapter 8). Soil is a complex material, often with more 'void' than solid. These voids, known as pores, can vary hugely in size. Some are tiny, only a few thousandths of a millimetre across, occurring between sheets of clay minerals. Others are tens of centimetres across, caused by burrowing animals or old roots that have decomposed. Their size is important because it determines whether a pore will hold water or not under given conditions. The ability of water to bind to soil particles means it is very difficult to extract it from small pores and not even plant roots can extract it from the smallest pores. However, in large pores, the water drains freely as soon as gravity acts on it.

Figure 5.4 The amount of water a soil can store (specific yield); the amount of water plants can obtain from the soil (available water capacity); and how fast water might flow through soil (hydraulic conductivity) can be derived from a simple graph known as a soil-moisture-release curve. This can be produced by a soil-physics laboratory. This example shows curves for four different soil types. The sand loses its water most quickly, the peat and clay loam, the slowest.



Specific yield represents the volume of the soil that is full of water when saturated but which drains freely when surrounding water levels drop. Imagine a flowerpot full of soil. Submerge it in a bucket of water for a day to saturate it, then take it out and immediately stand it in an empty bucket. The specific yield of that soil will be the volume of water that flows out into the second bucket.

Available water capacity is the amount of water in a drained soil that is available to plants.

Hydraulic conductivity describes the ease with which water flows through a given soil and depends on characteristics of the pores and the degree of saturation.

Specific yield (the volume of water within soil that can drain out) is usually measured in a soil-physics lab. The soil sample to be measured must be as undisturbed as possible to ensure its physical properties are not altered. The sample can be taken by pushing a small metal ring (typically 5 cm diameter and 5 cm high) into the soil and then gently lifting it out with a trowel so that the soil remains undisturbed within the ring. Once in the lab, the core is saturated to fill all its pores with water. It is then weighed and the water is extracted gradually whilst repeatedly weighing the core to build up a picture of how readily the pores release their water (see Figure 5.4). A soil with a high specific yield, such as a well-structured peat or loam, contains lots of large pores, which are able to store a lot of water. The water table in such a soil will move gradually in response to rain. By contrast, soils with low specific yield such as a compacted alluvium lack large pores and store very little water, so the water either sits on the soil surface or the soil is apparently dry. There may be no measurable water table in such a soil.

The bigger the pores are in a soil, the faster water will move. Hydraulic conductivity values indicate how fast water can move through a soil. Soil with a high hydraulic conductivity (0.5 m/day) is regarded as permeable and water can move quite readily between the soil and nearby ditches and rivers. A soil with a hydraulic conductivity below 0.05 m/day is effectively impermeable and water cannot pass through it fast enough for water levels to approach equilibrium with those in surrounding watercourses. For a floodplain-meadow manager, it is important to know the permeability of the soil because this determines how important the water level in ditches is (and the number of ditches) in maintaining the water table of the meadow.

Compaction

Compaction is the biggest threat to the soil of a floodplain meadow. It can alter plant-community composition, as compacted soils become more waterlogged, leading to the development of relatively species-poor inundation communities and invasion by less palatable species such as rushes. Compaction reduces the abundance of soil invertebrates and may impact on soil-surface invertebrates such as beetles and spiders. It can also reduce the ability of a site to store floodwater and re-charge the aquifers below.

Alluvial soils are naturally very well-structured, providing plenty of pore space for air and water to move through the soil. However, such soils are susceptible to compaction when wet. A soil loses its strength when close to saturation and cannot bear the weight of a vehicle or a grazing animal.

A compacted layer exposed by a soil pit. There are few, if any, visible pores and cracking tends to be horizontal. There is no space for air and water. Most plant roots cannot tolerate such soil. © Emma Rothero

Heavy machinery running across soil that is too wet can cause long-term damage to soils by compaction. © Mike Dodd

The result of such activity can be seen at Avon Meadows, Worcestershire where clear lines of hard rush have grown in tractor tracks created as a result of hay cutting when the soil was too wet. Hard rush is one of the few plants that thrives in compacted soil. © Ken Pomfret

A small soil pit on the Thames floodplain, which was used to take undisturbed cores from the upper two horizons so that the bulk density of the soil and its moisture-release characteristic could be ascertained back in the lab. The soil from the pit is laid out to illustrate the profile, with soil from the darker 'A' horizon on the right, which is rich in organic matter and about 25 cm deep, from the paler 'B' horizon 45 cm deep, composed of fine textured alluvium with less organic content, but good structure nevertheless and on the left from the orangey 'C' horizon, which is the top of a sandy terrace deposit. © David Gowing

Compaction occurs when a wheel or hoof penetrates the mat of grass roots at the surface and sinks into the soil, creating a rut or deep hoof-print. The soil particles are squashed together, eliminating the pores between them. Once a soil is compacted, it can take decades for the pores to re-form in anything like the pattern that occurred prior to the damage.

Conserving the structure of the soil is a vitally important role for anyone involved with meadow management. Elsewhere in Europe, some meadows are never grazed in order to protect their soil structure. Simple precautions, like letting some air out of the tyres of hay trailers, can provide real benefits by spreading the weight of the load over a greater surface area and avoiding the production of ruts.

A simple way of detecting the degree of compaction is through measuring *dry bulk density* – the weight of dry soil within a specified volume of soil, measured in kg/litre.

To assess dry bulk density an undisturbed core of known volume (typically 100 cm^3) should be taken, dried in an oven at 105°C for 48 hours and then weighed. Table 5.4 summarises some typical values.

Wider values and benefits

Soils are at the root of everything related to floodplain meadows. The physical characteristics outlined above will affect the nutrient status of the meadow, its ability to facilitate the movement of water, store carbon and to supply nutrients to plants.

Examples of the wider benefits that floodplain meadow soils can provide are:

- floodwater storage (see Chapter 7);
- purification: reduced diffuse pollution by trapping sediments and uptake of nutrients, particularly N and P (see Chapter 6);
- nutrient cycling (see Chapter 6); and
- climate regulation: sequestration and storage of carbon and other greenhouse gases.

Carbon storage in floodplain-meadow soils

Recent estimates of carbon storage in UK soils vary depending on the habitat type and land use. It is estimated that grazed grasslands can sequester 0.6 t ha^{-1} yr^{1} whilst the conversion of permanent grassland to arable will release between 1.0 and 1.7 t ha^{-1} yr^{1} (Alonso *et al*. 2012).

Table 5.4 Some typical dry bulk density values for soils (values less than 1.0 suggest the soil is light enough to float on water).

	Fine textured soil (clay)	Coarse textured soil (sand)	Organic soil (peat or humic loam)
Good structure (e.g. old grassland)	0.95	1.10	0.80
Disturbed structure (e.g. arable reverted to grassland)	1.15	1.40	0.95
Compacted soil (damaged soil through heavy grazing or the use of heavy machinery whilst wet)	1.40	1.75	1.10

Wetlands are found to retain higher amounts of carbon, but figures apply to habitats that are permanently wet, rather than seasonally wet. An assessment of carbon stored in agricultural soils shows grazed grasslands are predicted to be a net carbon sink, as opposed to arable land, which is a net carbon source (Alonso *et al*. 2012). Floodplain meadows are grasslands, wetlands and agricultural land, so the soil carbon figures applied to them are best estimates. Further work is currently being undertaken to assess in more detail the actual carbon storage potential of floodplain-meadow soils across hydrological gradients.

This tapestry by Jean Widdows (Cricklade, Wiltshire) was inspired by a talk given by David Gowing about North Meadow. It depicts the soil profile photographed on the bank of the River Churn by Mike Dodd (page 27) and is a more unusual example of the cultural benefits provided by floodplain meadows. Photo © John Barratt

The tapestry shows the 'O', 'A', 'B' and 'C' horizons described previously. In this case the 'O' horizon (brown layer) contains decaying plant litter.

The 'A' horizon (orange layer), is well-drained clayey alluvium, its colour reflecting the rusting of iron minerals.

The 'B' horizon (grey layer) is also clayey alluvium, but as it is mostly underwater, rust compounds are converted back to grey iron-containing minerals due to the lack of oxygen.

The bottom, light coloured layer 'C' horizon, is much coarser, revealing limestone gravel washed in from the Cotswolds historically.

Many thanks to additional contributor Jean Widdows.

Chapter 6
Nutrients

David Gowing

This chapter describes the impact of nutrients on the plant-species composition of floodplain meadows. It outlines the role of different nutrients in the overall balance of floodplain meadows in terms of input, outputs and nutrient cycling. Case studies provide examples of nutrient budgets and highlight issues surrounding the impact of waterlogging on nutrients.

Nutrients are a key factor determining plant-species diversity and therefore an important aspect to consider in the management, conservation and restoration of floodplain meadows. The key position floodplain meadows held in the nutrient cycle of traditional agricultural systems made them a really important part of English social history (Brian 1994). Naturally productive because of the nutrients deposited by river silts during floods, they are nonetheless vulnerable to excessive amounts of nutrients, particularly nitrogen (N) and phosphorus (P).

Nutrients and plants

All plants have a positive requirement for at least 13 different mineral elements (Marschner 1986) in addition to the carbon, hydrogen and oxygen that form the main structural components for growth. Three of these minerals tend to be needed in such quantities that plant growth can be limited if they are not readily available: nitrogen, phosphorus and potassium (K). It is these three elements that farmers most frequently supply to crops as artificial fertiliser and primarily these three that affect both the growth rate and the community composition of natural and semi-natural grasslands. Most of the other mineral nutrients are only required in trace amounts so these minor nutrients do not often limit growth.

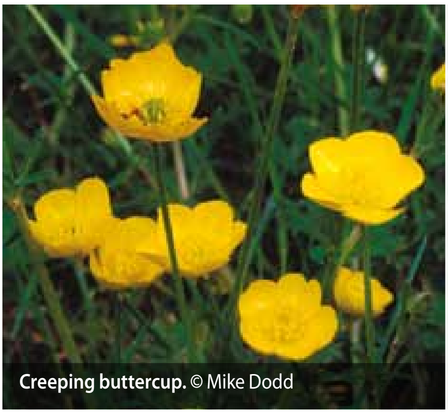
Nutrient availability affects overall species-richness. In situations where nutrient levels are high, bulky, competitive plants prevent other species from becoming established. Conversely, where nutrient levels are very low, only a few specialised species can flourish. Species-richness is therefore greatest where nutrient levels are intermediate (see Figure 6.1).

When mineral nutrients are abundant, a few aggressively competitive species tend to dominate the plant community as their growth is not limited by lack of nutrients (see Table 6.1,

Table 6.1 Species found on floodplain meadows differentiated by their nutrient requirements and tolerance to cutting/grazing.

A. Very competitive species (require high nutrient levels and relatively intolerant of cutting/grazing)	B. Nutrient-demanding species (tolerant of cutting/grazing)	C. Species tolerant of nutrient-poor conditions and cutting/grazing
Common couch	Perennial rye-grass	Yellow-rattle
Creeping thistle	Creeping bent	Carnation sedge
Common nettle	Meadow foxtail	Pepper-saxifrage
Comfrey	Hogweed	Quaking-grass
Broad-leaved dock	Creeping buttercup	Cowslip
Cleavers	Curled dock	Field wood-rush
Reed sweet-grass	Spear thistle	Adder's-tongue


Comfrey. © Mike Dodd


Creeping buttercup. © Mike Dodd


Adder's-tongue. © Peter Creed

section A). Where nutrient levels are moderate, these give way to other competitive species that are still nutrient demanding but less so than the most aggressive species, for example where regular management removes biomass (and therefore nutrients) from the system (see Table 6.1, section B). Where nutrients are most limiting, the competitive species are unable to access sufficient minerals and are replaced by species that are specialised in extracting nutrients from poor soils (see Table 6.1, section C). These more specialised plants are often uncommon or rare in agriculturally improved lowland landscapes, where nutrient-hungry competitive species predominate.

Nutrient balance

The availability of soil nutrients is determined by the balance between inputs (for example sediment deposition, nitrogen fixation and atmospheric deposition) and outputs (such as the hay crop and weight gain by grazing livestock). All mineral nutrients are dynamic – their availability changes with time – but some are more dynamic than others. The availability of N varies markedly from week to week depending on the weather and shows strong seasonal oscillations, whilst the availability of P tends to vary only gradually from year to year. The following sections consider the various inputs and outputs of this balance in more detail.

Sediment deposition

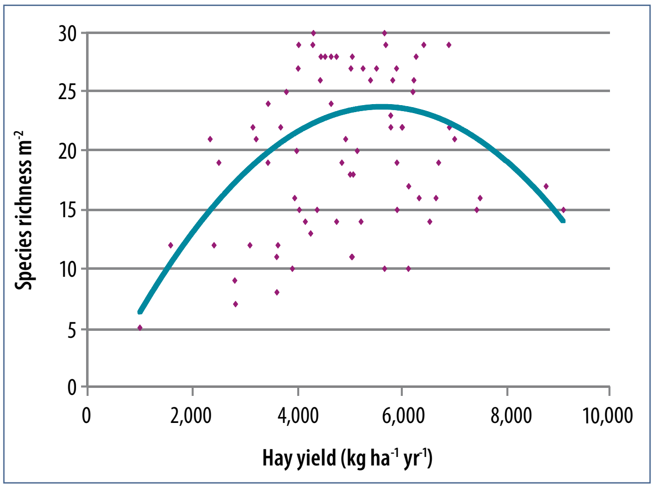
The largest natural input of nutrients to a floodplain meadow is from sediments deposited during a flood event. This material is derived from soils and rocks eroded within the river catchment, combined with detritus from the aquatic ecosystem and from vegetation washed into the water. Fine sediment builds up on the bed and banks of the river during periods of low flow, is re-suspended during a flood and then deposited across the floodplain when the river overtops its banks. In catchments with intensive agricultural land use, floodwaters also bring the residues of artificial fertilisers, while in urban catchments waste water overflows can also increase nutrient levels.

Available nutrients

When considering nutrient status in soils, there are two pools to take into account: the total pool and the available pool. In this context, the term 'available' indicates a chemical form of the mineral which is potentially soluble and therefore able to be taken up by plant roots. Taking N as an example, the available pool corresponds to the amount of nitrate and ammonium ions plus any free amino acids in the soil, as these are the soluble forms a plant can take up through its roots. The total pool of N includes the litter and humus in the soil, in which N atoms are bound within large complex organic molecules that are unavailable to plants.

The total pool is often orders of magnitude greater than the available pool. For example, a peat soil may be 1% N by mass, but less than one-thousandth of that N is in a soluble form available to plants, so their growth may be limited. It is therefore essential when interpreting soil nutrient data to be very clear whether measurements supplied relate to the total pool or the available pool.

Figure 6.1 The relationship between productivity and species-richness in floodplain meadows. The greatest species-richness is found where hay yields are between 4,000–6,000 kg ha^{-1}yr^{-1} (McGinlay 2013).



Nutrients and animals

Herbivores and most fungi derive their mineral nutrition from the consumption of living and dead plant matter, so their populations are reliant on the productivity of vegetation rather than the availability of nutrients in the soil. Nevertheless, soil nutrient status may be important for animals, particularly domesticated animals such as sheep and cattle. If the soil is deficient in trace nutrients such as magnesium and copper, plants may still grow normally (as their requirement for these minerals is very low), but their tissues will have low concentrations of these elements. This can lead to mineral deficiencies in the livestock and consequent disease, so mineral supplements (saltlicks) often need to be supplied.

For the key plant nutrients (N, P and K), the vast majority of what grazers eat is excreted in their urine and faeces, so grazing is not an effective method for removing nutrients from a site. In fact, because faeces decompose faster than plant litter, grazing animals can boost the fertility of a grassland by converting nutrients into a more readily available form.

Belted Galloway cattle grazing floodplain meadows at Clattinger Farm, a Wiltshire Wildlife Trust reserve. © Mike Dodd

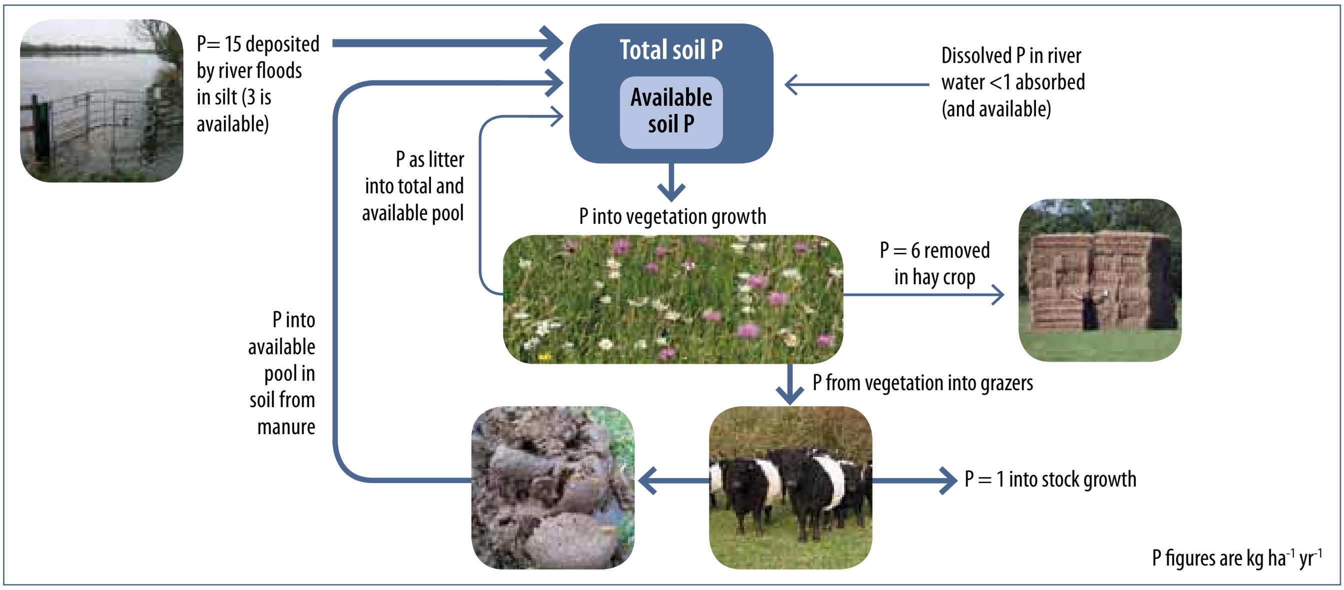


Figure 6.2 The P cycle on a floodplain meadow showing the amount of P in kg ha^{-1} yr^{-1} deposited and removed in a year with a major flood. In this instance the total pool of P stored in the soil will have increased by 9 kg ha^{-1} over the year.

The amount of available P in meadow soil can increase as a result of sediment deposition and this can affect the composition of the plant community. Case Study 6.1 demonstrates the range of sediment deposition on sites across the UK recorded after the summer floods of July 2007 and shows that extreme events can lead to very high sediment deposition, for which management action should be taken as a matter of some urgency (see Chapter 9). However, there is no clear correlation between water quality in a river and the rate of nutrient deposition onto its floodplain – the amount of P in the water column is not necessarily linked to the amount of P in the bed sediments. It is not safe to assume that a river with good water quality will deposit sediment with a low P content on floodplain meadows.

The P cycle in Figure 6.2 demonstrates that the largest input of P to a floodplain meadow is from silts deposited by floods, and the largest loss of P is through the annual hay crop.

Fungi and bacteria

Fungi and bacteria dwelling in the soil form a critical part of the ecosystem because they decompose organic matter and in so doing release minerals that again become available for plants to take up. The rate at which soil microbes decompose this dead material itself depends on the availability of nutrients, particularly N and P. Addition of these nutrients to the soil can accelerate the decomposition process, resulting in more nutrients being released and a decrease in the organic matter content of the soil.

Legumes

Legumes, members of the pea family, can play an important role in the N budget of a floodplain meadow due to their ability to form a mutually beneficial relationship with bacteria that occur in their root nodules. These bacteria are able to convert N gas into organic N compounds such as amino acids, which plants, animals and fungi can use. Legumes are favoured by conditions in which the availability of N in the soil is sufficiently low to limit the growth of their competitors. In such conditions, legumes such as red clover, meadow vetchling and tufted vetch can form a substantial component of the plant community of a floodplain meadow. Other legumes found in floodplain meadows include white clover, common bird's-foot-trefoil, lesser trefoil and bush vetch. The N contribution to the soil from legumes can be a major component of the N budget.

Atmospheric nitrogen deposition

Nitrous oxides (produced by the burning of fossil fuels) and ammonia (resulting from intensive animal rearing and heavily fertilised land) travel through the atmosphere and are re-deposited on vegetation and in rainfall. The background deposition rate pre-industrialisation was only 1–2 kg ha^{-1} yr^{-1} with most of the nitrous oxides arising in electric storms. Current rates of atmospheric deposition can reach 30 kg ha^{-1} yr^{-1} in England and 15–20 kg ha^{-1} yr^{-1} is typical – this is about 15% of the amount of fertiliser used on swards managed intensively for silage[26]. Floodplain meadows are subject to this input along with all other habitats; the net effect is that the productivity of meadows, which is usually N-limited, may increase and become P-limited instead. One effect of this change is an increase in grasses, most of which benefit from improved supplies of readily available N, and a corresponding decrease in legumes, which rely on the N-limitation of their neighbours to help them compete for light and other resources. Management issues related to atmospheric N deposition are discussed in Chapter 9.

Hay cutting and grazing

Biomass stripping (such as hay cutting) is the major route by which mineral nutrients, particularly P, leave a floodplain meadow. Hay cutting can typically remove four tonnes of dry biomass from a hectare (ha) of meadow (Gowing, Tallowin *et al.* 2002). Dry biomass is about 0.2% P by weight, so the amount of P being removed annually is about 8 kg ha^{-1} yr^{-1}. Assuming hay cutting is repeated annually, this suggests that about 80 kg of P can be removed per decade, which, depending on the soil type, may represent a substantial proportion of the available pool of P. In nutrient-enriched meadows, where growth is not limited by phosphorus availability, it is therefore possible to lower the nutrient status of the soil substantially through annual hay cuts.

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[26] E.g. see British Grassland Society's silage decision factsheets: http://www.britishgrassland.com/page/fact-sheets

Red clover, tufted vetch, meadow vetchling, white clover and common bird's-foot-trefoil. © Mike Dodd

The nitrogen cycle

Within floodplain meadows, N is a much more dynamic nutrient than P. The available pool of soil N is probably less than 50 kg ha^{-1} at the start of the growing season; the majority of the N taken up by plants enters the available pool of N in the soil during the course of the season from a range of other sources. In particular, it is the rate of mineralisation (the release of N from organic matter into soluble form) that controls the availability of N to plants, rather than the size of the available pool at any one point in time. The rate of mineralisation depends primarily on soil temperature and soil moisture. Organic matter decomposes most rapidly when the soil is warm and there is an appropriate balance between soil air and soil water.

Mycorrhizal fungi

Mycorrhizal fungi live in mutually beneficial relationships with a broad range of plants. They exist as long strands known as hyphae, which grow through the soil and derive their energy from the roots of their host plant, which supplies them with sugars. In return, they supply the plant with nutrients, notably P, which the fungi are more efficient at gathering from the soil than is the plant. Many plant species may rely on suitable fungal populations being present in the soil, however, little is currently known about their role in floodplain meadows. The loss of these fungi may be one reason why plant communities take a very long time to recover following long-term flooding on floodplain meadows and may also be a consideration in the re-creation of floodplain meadows on arable sites.

Grazing does not play a key role in nutrient removal. More than 90% of the nitrogen consumed by herbivores is re-deposited as urine or dung (Parsons *et al.* 1991), so there is negligible nutrient removal from the meadow. Dairy cattle are an exception, but the use of floodplain meadows for dairying is very uncommon as this needs well-fertilised grass and the sites are too wet for heavy animals. The consumption and re-deposition of nutrients tends to enhance their availability by speeding up nutrient cycling, so grazing is not a useful tool to control excess nutrients directly (Hassink and Neeteson 1991). However, grazing has an important role in suppressing coarse, vigorous species, creating gaps in the sward for plants to regenerate and so maintaining species-richness, although this addresses a symptom of high nutrient availability rather than the problem itself (Latinga *et al.* 1999).

Consistent hay cutting can lead to a decrease in competitive species and an increase in species tolerant of nutrient-poor conditions, such as those listed in section C of Table 6.1.
© Jim McGinlay

Benefits of nutrient cycling in floodplain meadows

The increasing use of fertilisers in agriculture over the past 70 years has resulted in increased levels of both nitrogen and phosphorus in watercourses and concerns over water quality. Nitrate is readily lost from soil through leaching and phosphorus is lost through soil erosion. Floodplain meadows may be able to improve river water quality through facilitating the deposition of sediment-bound phosphorus and the removal of nitrogen (Cook 2007), as small doses of phosphorus (P) and nitrogen (N) can be absorbed by floodplain meadows and turned into an economically valuable agricultural crop.

In this way, excess N and P can be removed from the catchment and forage produced for animals without the need for artificial fertilisers. This is a very sustainable agricultural system and an excellent method for reducing unwanted nutrients (and fine sediment) in rivers, ultimately resulting in improvements in downstream water quality.

Many existing meadows are not managed to maximise the hay yield (and therefore the removal of N and P) but instead are cut late in an effort to deliver a range of conservation objectives rather than agricultural productivity. A better understanding of the system shows that the two objectives

The role of soil pH

pH is a measure of acidity. Floodplain meadows have more or less neutral soils with pH values between 5.5 (slightly acid) and 8.0 (slightly alkaline). The soil pH is important in terms of mineral nutrition because it controls the solubility, and therefore the availability, of nutrients. P availability declines at high pH, so soils with limestone fragments can have their productivity limited by a reduction of available P.

Lime (calcium carbonate) is the substance most likely to affect soil pH as it releases calcium ions in the presence of acids, thereby neutralising them and raising the soil pH. Limestones are quite readily eroded by water so lime-rich rocks anywhere in the catchment will tend to influence the pH of the river, its sediments and thus its floodplain. Calcium (Ca^{2+}) and related basic ions potassium (K^+) and magnesium (Mg^{2+}) are leached from the topsoil by rain, which is naturally acidic and especially so when fortified by nitrous oxides. All soils in the UK are at risk of leaching and the surface layers become acidic unless balancing mechanisms are at play. In the case of floodplain meadows, this balancing process is the deposition of flood sediment. Many of the large river catchments in England hold some lime-rich rock so these rivers tend to have substantial concentrations of calcium ions. The calcium ions are deposited on the meadow during floods, where they neutralise any acidity which may be developing. Where floodplain meadows have been disconnected from the river, for example by embankments, there is a risk of surface acidification in the soils, which tends to lead to a loss of species-richness.

Most of the plant species typical of floodplain meadows are able to grow across the range of pH values, but some, such as fairy flax (pictured) and common bird's-foot-trefoil, are favoured by higher pH. © Mike Dodd

do not conflict; the meadows have developed as a result of centuries of agricultural management to produce a productive crop, by cutting hay when it is at its most productive. Nutrient removal from a catchment will only be effective if the meadows are fairly extensive, managed as an agricultural crop and the hay is cut when it is ready, and not later. To exploit the nutrient-cycling functions of floodplain meadows, they should be cut and managed as an agricultural crop. Chapter 9 gives more detail on management prescriptions.

Managing nutrient budgets

Knowledge of the nutrient budgets of floodplain meadows is essential when planning management and understanding the likely impacts of restoration measures. This is addressed in Chapter 9, with relevant information also in Chapter 10, and Chapter 11. In most cases, it will be necessary to send soil samples to a soil-analysis lab to obtain measurements. Useful information can also be obtained through mineral and yield analysis of hay.

Plants such as nettle (*Urtica dioica*) can become a problem where there is consistent late cutting and/or excess sediment deposition, resulting in the nutrient budget being out of balance. © Mike Dodd

CASE STUDY 6.1
Impact of summer flooding on floodplain biodiversity from nutrient deposition

The fluvial floods of June/July 2007 were some of the largest on record in the UK. They deposited substantial amounts of sediment across many of our floodplains and raised questions about whether floodplain habitats would be impacted by eutrophication through phosphorus enrichment. In particular, did summer floods deposit sediments with high phosphorus content due to waste-water treatment works being overwhelmed by intense rainfall? A research project was established to examine this question in more detail with objectives to:

1. estimate the amount per hectare of total phosphorus, available phosphorus and basic cations delivered as sediment following a substantial summer flood;
2. assess the importance of summer-flood delivered sediment in the context of a floodplain grassland's nutrient budget; and
3. assess the likely impact of higher frequency summer flooding on biodiversity.

In order to do this, species-rich floodplain meadows at potential risk from eutrophication in five catchments that had experienced floods (Thames, Severn, Trent, Ouse, Derwent) were visited. Ten sites were visited in August 2007 to collect a total of 100 samples of sediment, soil and hay as soon as possible after the floodwaters retreated. Samples were dried, then analysed to measure concentrations of phosphorus and major cations (calcium, magnesium and potassium).

The survey found that concentrations of total phosphorus levels varied widely. Some sites received no measurable sediment, even though they had been inundated, whilst other sites received as much as 500 kg P per hectare in total (see Figure 6.3). On these sites, deposition of Olsen-extractable phosphorus varied from 1 to 32 kg P/ha and deposition of potassium ranged from 2 to 270 kg K/ha.

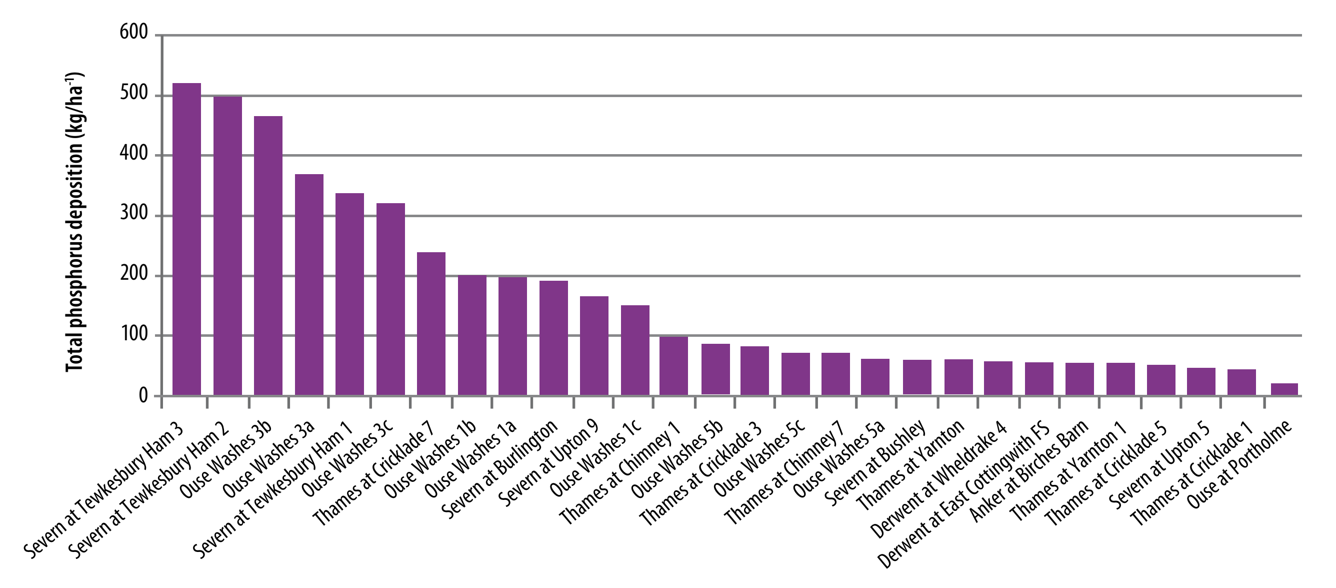
Previous data have shown that phosphorus export out of a meadow in the form of hay typically accounted for 6 kg ha^{-1} yr^{-1}, suggesting it would take about five years to balance just the readily available phosphorus (30 kg/ha) in the new sediment. Considering the total phosphorus deposited, a proportion of which would become mobilised in future, the time frame could be much longer (up to 35 years) and therefore regular floods on this scale would threaten the conservation value of the grassland.

Small pieces of astro turf (weighed in advance and pinned down with pegs), called 'sedimats' are used to capture sediment deposited during a flood. They must be placed on site before a flood and then collected and removed to a lab afterwards. © Mike Dodd

The concentration of total phosphorus in the summer-flood sediments was not significantly different from winter-collected samples overall, but the extreme values were higher.

Floodplain meadows provide an important ecosystem service by trapping sediments during floods. The results of this study showed as much as 40 tonnes of sediment per hectare were retained by the meadows, which avoids a considerable amount of material from silting up channels or fouling structures downstream. The phosphorus contained in that sediment is effectively trapped by the meadow from where it is and then gradually exported in terms of an agricultural product, the annual hay crop, for several decades. In this way, floodplain meadows serve as an ideal cleansing filter turning a potential problem (nutrient-laden sediment) into a useful product (hay).

Figure 6.3 The total phosphorus deposited in sediment per unit area across a range of sites.



CASE STUDY 6.2

Investigating the nutrient budget of the Oxford Meads, Oxfordshire

To understand the nutrient dynamics at a site, it is useful to establish the nutrient budget. This helps to clarify the main P inputs and offtakes in order that the site can be managed to remain in nutrient balance, with P inputs not exceeding offtake. Big floods (as demonstrated in Case Study 6.1) can bring in very large quantities of P, which need to be balanced by prompt management the following year to avoid changes in the plant communities.

In order to do this on the Oxford Meads, samples of soil and hay were collected from Pixey, Yarnton, Oxey and Cassington (part of the Oxford Meadows SAC), as well as the nearby New Marston Meadows SSSI, 2008. A vegetation survey was also carried out.

Soils

Three soil samples were taken from each of the six botanical monitoring blocks across the Meads. An additional 24 samples were taken from areas not well-represented by the monitoring blocks, and four additional samples were taken from New Marston Meadows SSSI. Sample sites were located within a range of plant communities. Soil samples were taken from the top 100 mm of the profile and each sample was composed of 12 separate 10 mm diameter cores, combined into a single pooled sample to smooth out fine spatial heterogeneity in soil properties. The soil was oven dried in Open University soil laboratories at 40°C, ground to pass through a 2 mm sieve and analysed for pH, total phosphorus, extractable phosphorus using the Olsen method and major cations (Ca^{2+}, K^{+}, Mg^{2+}, Na^{+}).

Vegetation (hay yield and composition)

At each of the soil-sample locations, the vegetation within one square metre was cut to 30 mm above ground level and weighed. A subsample (350 g) was then selected and rapidly dried in a fan oven. The dry weight was determined to calculate yield, then the sample was ground and digested in perchloric acid and analysed for N, P, Ca, K, Mg and Na.

Sediments

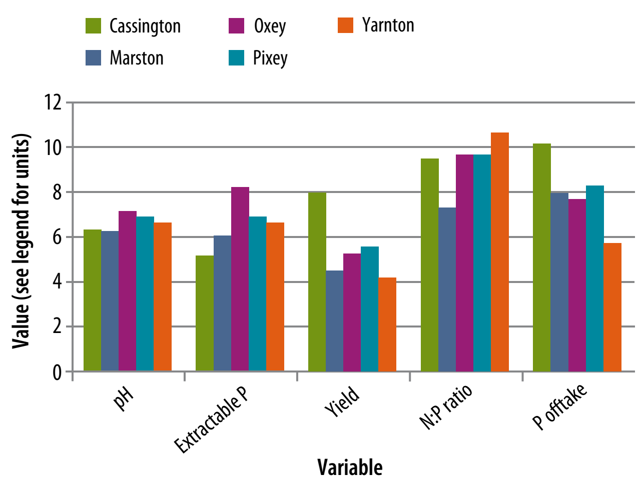
Nutrient traps made from pieces of astro turf (designed to mimic the roughness of grass) were set out across the meads to measure sediment deposition. Fourteen traps were spread across Yarnton and Pixey Meads in December 2007 and retrieved in April 2008. The traps were returned to the laboratory where the sediment was weighed to estimate the amount of silt deposited per hectare and then analysed for phosphorus (both total and extractable content).

Results

The data collected enabled a description to be made of the nutrient status of the meads during 2008, and provided a reference data set against which future changes can be compared (see Figure 6.4). The nutrient status of a floodplain meadow is highly dynamic and it is a function of the site's hydrology. The size of the last flood and the interval since it occurred are major determinants of the system's phosphorus status.

Soil samples were taken from within a 1 x 1 m area.
© Mike Dodd

Figure 6.4 Five soil and hay variables at different floodplain meadows. pH is in standard units; extractable phosphorus (P) is mg/kg^{-1} by the Olsen method; yield is t/ha; N:P ratio is dimensionless; phosphorus offtake is kg/ha.



Many thanks to additional contributors Jim McGinlay and Irina Tatarenko.

Chapter 7
Water

Sophie Lake, Emma Rothero, Ann Skinner and Hilary Wallace

Water is a key factor in shaping the character of floodplain-meadow plant communities. An understanding of the importance of water to floodplain meadows and how the hydrological regime of a site functions is important in informing management and restoration decisions. This chapter outlines typical hydrological regimes and their influence on plant communities, and explains the importance of soil structure to the hydrology of a site. Case studies describe the way topography influences the vegetation through its role in determining water levels, and the role of floodplain meadows in flood storage.

Why water is critical to floodplain meadows

Water levels play a key role in floodplain meadows. Flooding is more usual in winter, although the timing, frequency and duration of floods vary from year to year. Less water is lost through evaporation in autumn and winter, and water levels tend to rise, falling again in the spring and summer when there is substantially more evapotranspiration. The characteristic floodplain-meadow plant communities are adapted to these changing conditions. Vegetation tends to recover well after winter flooding, as the plants are not actively growing. However, prolonged or deep summer flooding, or ponding of water in depressions, can lead to the deterioration of soil structure and the development of anoxic conditions, both of which are detrimental to the characteristic plant communities. Case Study 4.1 (Chapter 4) discusses the consequences of flooding and subsequent changes to management practice on plant communities at North Meadow, Cricklade.

For centuries, floodplain management, including the creation and maintenance of ditch systems for land drainage, has influenced the vegetation. The plants and associated

Sediments (silts) containing plant nutrients such as nitrogen and phosphorus are deposited during floods and these can boost the productivity of the vegetation in the following growing season. North Meadow. © Mike Dodd

There are no truly natural floodplains in Britain today, with most rivers being straightened, deepened or embanked to some degree. Floodplain meadows have developed through human interaction with the land; they flourish where their hydrology continues to be managed appropriately. The photo shows the River Derwent embanked adjacent to East Cottingwith Ings SSSI, with the river level now higher than the meadows. © Mike Dodd

wildlife have adapted to cope with and indeed thrive under the hydrological conditions created and maintained by traditional management. Changes to traditional hydrological regimes may therefore adversely affect the integrity of floodplain meadows, so ensuring appropriate water levels are maintained is a key part of meadow management.

Different hydrological systems found on floodplain meadows

Floodplain meadows have developed across a range of hydrological systems, but the one constant is a soil-water regime which adequately supplies both oxygen and water to the root zone for the majority of the year. It is important to understand the hydrological system on a site because this has implications for site management objectives and the way these may be achieved. At least three different hydrological mechanisms for floodplains have been identified and modelled (Gowing *et al.* 1997):

- shallow aquifer-fed;
- ditch-drained peat; and
- ridge and furrow topography.

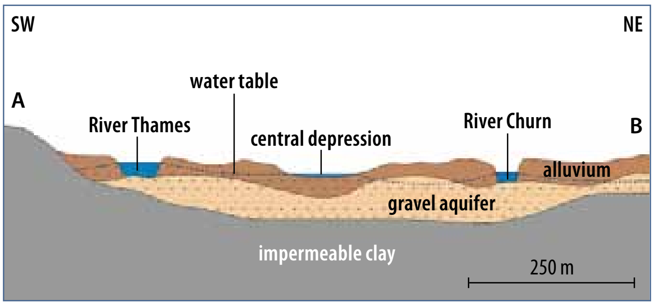
Examples of a shallow aquifer-fed system and a ditch-drained peat system are described further in Case Studies 7.1 and 7.2. In both cases it can be seen that only very small differences in topography are needed to sustain a wide range of grassland and swamp plant communities.

Shallow aquifer-fed systems

In these systems, the water in the soil can move up from the aquifer during summer to replace water in the soil lost through evapotranspiration, and downwards in winter following rainfall. Water can also move laterally through the soil between watercourses, usually the river and a back drain or, as in Figure 7.1, between two rivers.

Figure 7.1 shows how water movement and levels in North Meadow are determined by the relative heights of river water in the Churn and Thames. In addition, variation in the permeability of the alluvium results in differences in the speed of water movement across the meadow while channels and banks created by old river meanders diversify the topography, providing wetter and drier areas with slightly different plant communities, depending on the requirements of individual species. For example, snakeshead fritillary requires periods of inundation, followed by rapid drainage in spring (so that the bulbs do not rot).

Figure 7.1 The geological profile of North Meadow (Cricklade). Terrace gravels form a shallow aquifer supplying water to the meadow and also enabling it to drain away rapidly after a flood. From Open University Ecosystems (S396) module. © The Open University 2015



Typical examples of floodplain meadows on alluvial soils in large river systems that demonstrate shallow aquifer systems include the Oxford Meads (on the Thames near Oxford), Portholme (River Great Ouse in Cambridgeshire) and Stanford End, Berkshire on the River Lodden.

Ditch-drained systems

These systems are common on peat soils, for example in the Somerset Levels and Moors (see Case Study 7.2 and Figure 7.2).

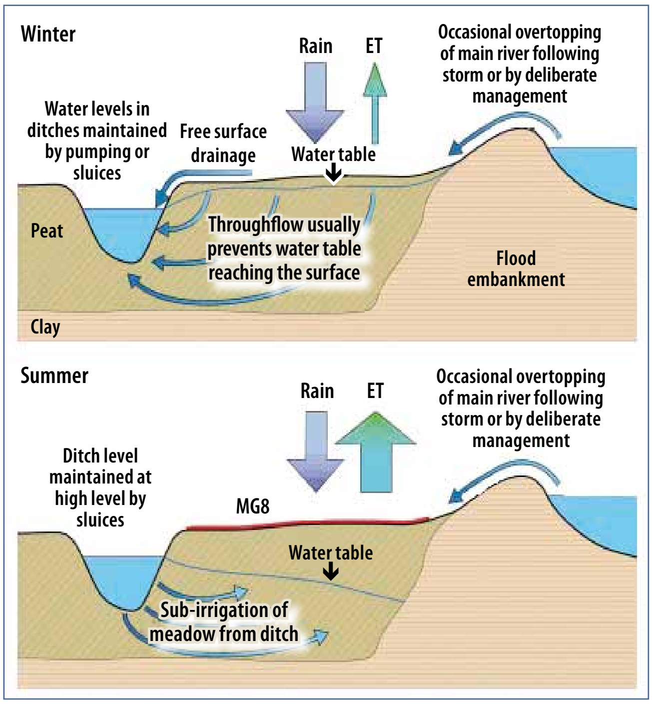
In winter and spring, when the ditches act as a drain from the meadow, the water table in the field is generally higher than the ditch level. Maintaining very high ditch levels in spring may damage the meadow flora by holding the water table so high that the soil becomes anoxic and the typical meadow system of microbes, invertebrates and plants is replaced by those of a swamp community.

In summer and autumn when the ditch-water levels are often held higher than the in-field water table, water can flow from the ditch into the meadow soil, helping to reduce drought stress to plants in the centre of the field.

Ridge-and-furrow systems

Floodplains with ridge-and-furrow topography have developed on land that was historically cultivated to increase productivity. The ridge-and-furrow land form was created as a result of regular ploughing. Plant communities on the higher and drier ridges are different from those in the lower, wetter furrows. Such meadows occur on the floodplains of the River Ray in Buckinghamshire and the River Whampool in Cumbria, and tend to have relatively free-draining soils over impermeable subsoils. These systems experience frequent flooding of the lower-lying areas. Water levels on such sites primarily respond to changes in rainfall and evapotranspiration – rivers and ditches generally only influence ridge-and-furrow systems when they burst their banks.

Figure 7.2 In the winter, ditch-water levels are held lower than field-water level, so the ditches act as drains. In summer, ditch-water levels are held (penned) higher than field-water level, so ditches act as irrigation channels and wet fences for livestock. See Wheeler *et al.* 2004.



How to determine the type of hydrological system at a site

Identifying and understanding the hydrological system of a floodplain meadow is critical to determining the best way to manage the site. There are three keys things to consider: water source, movement and regime (see Table 7.1).

Plant indicators of waterlogging and drought

Individual plant species have different tolerances to waterlogging and soil drying, and the number of weeks during which a plant experiences waterlogged or dry soil conditions will determine its distribution within a meadow. Identifying the distribution of key plant species can therefore provide a lot of information about a site's hydrology. The tolerances of many floodplain-meadow species have been quantified (Gowing, Lawson *et al.* 2002[27]) and some examples are shown in Figures 7.3 and 7.4 below. For example, bulbous buttercup prefers drier conditions and is rarely found on waterlogged soils (Figure 7.3, top left) or those kept constantly moist (bottom left). Creeping buttercup prefers waterlogged soils and is largely absent from those which are dry for much of the year (bottom right), whereas meadow buttercup occupies an intermediate position between the other two. Meadowsweet (Figure 7.4) will tolerate wetter conditions than great burnet but silverweed is far more tolerant of waterlogged conditions than either of them.

The approach shown in Figures 7.3 and 7.4 has been used for 99 other plant species of floodplain meadows (Gowing, Lawson *et al.* 2002[27]). Information on plant indicators of different conditions is also given in Chapter 9. Species with similar waterlogging tolerances will tend to grow together, so different plant communities will occupy discrete positions on the waterlogging/soil-drying gradient (see Chapter 8).

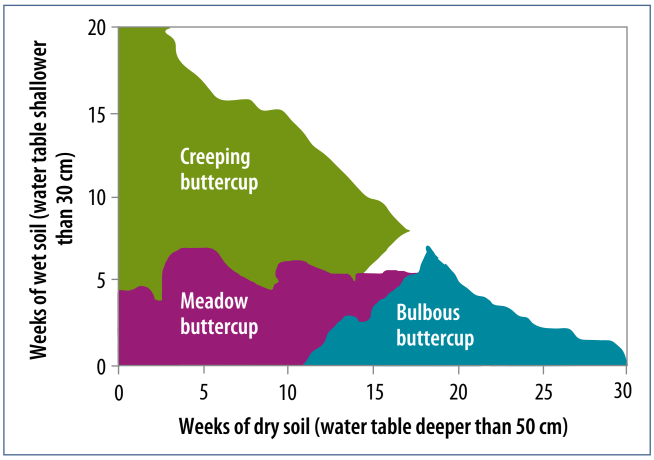


Figure 7.3 The segregation of buttercup species according to the wetness of the soil on floodplain meadows.

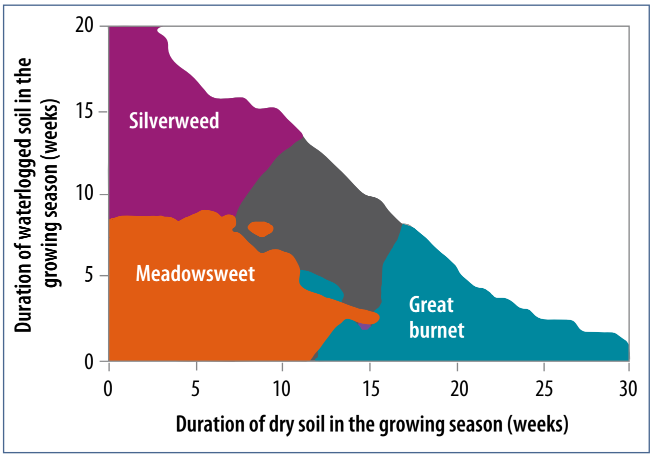


Figure 7.4 The segregation of representatives of the rose family according to the wetness of the soils on floodplain meadows.

Meadowsweet, great burnet and silverweed are all members of the rose family but they occupy different places on the hydrological gradient, as shown in Figure 7.4. Photos: Meadowsweet and great burnet © Mike Dodd. Silverweed © Peter Creed

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[27] http://www.floodplainmeadows.org.uk/sites/www.floodplainmeadows.org.uk/files/files/research_zone/d96437.pdf

Table 7.1 Tips for investigating the hydrology of a floodplain meadow.

Key element	Question	How to find out about it
Water source	Is the water purely surface water from flood events?	Observe water retention on the site after a flood: is there water on the site/moist soil during drier conditions? Use plant indicators such as carnation sedge, which is indicative of permanently moist ground
	Is there groundwater seepage from spring lines or watercourses?	Use plants as evidence, see above; are there water-requiring species up slopes?
	Is there a sand or gravel layer beneath the alluvium allowing lateral water movement?	Use a soil auger to determine the soil profile (see Chapter 5)
Surface-water movement	What is the direction of flow around the site?	Which way do ditches flow? Which way do floods go?
Groundwater movement	What is the depth of water in the soil and how does the elevation of the water table vary across the site?	Is it constant throughout the year or does it vary depending upon season? Install dipwells to measure water tables throughout the year (Chapter 11) Use a soil auger to determine extent of soil moisture (Chapter 5 and Chapter 10: Case Study 10.1 Fotheringhay)
	What is the slope of the water table across the site?	Measure hydraulic conductivity using the auger-hole method (Chapter 5)

The relationship between water and oxygen in the soil

Plants need water to grow but they also need oxygen. The pore space in soil is either air filled or water filled. Meadow species require a balance, with some pores full of air and some full of water. Well-structured soil with lots of pore space and pores of varied sizes is more likely to fulfil this condition and support a rich community of plant species. Soils with low porosity are likely to experience extremes of both waterlogging and drought, so will only support the few species that are resilient to both conditions (see Chapter 9 for information regarding the management of soil structure and the avoidance of compaction).

With increasing temperature, oxygen solubility in the soil water decreases (Hutchinson 1957) and the amount of oxygen demanded by soil microbes and plant roots increases. Therefore oxygen availability becomes increasingly critical as temperatures rise in the spring. If the soil has insufficient air-filled pores, the soil becomes anoxic and the typical floodplain-meadow communities of microbes, plant and soil invertebrates will change. The factors influencing the amount of oxygen within the soil are soil structure and water-table position.

Waterlogging and soil drying

Waterlogging occurs when almost all the pores are water filled and too few contain air. In waterlogged conditions, oxygen cannot diffuse through the soil effectively. It is generally considered that more than one tenth of the total volume of soil must contain air to allow sufficient diffusion of oxygen to maintain root function. Below this level, plant roots are unable to acquire enough oxygen to respire. When this happens, the soil is referred to as anoxic and the plants are said to be under aeration or waterlogging stress. Anoxic conditions affect soil microbes, many of which also require oxygen to respire. Anoxia reduces the rate of decomposition, which reduces the rate at which nutrients are recycled. It can also result in the production of ferrous and sulphide ions, which are toxic to plants.

Soil drying occurs when the soil pores are full of air and there is insufficient water. Soil drying can be an issue in floodplain meadows in summer, although this stress tends to be less of a threat than anoxia (Wheeler *et al.* 2004). The structure of the soil (its porosity) influences the ability of plants to obtain enough water and determines the depth of water table below which plants will experience stress from soil drying. Soil drying can restrict the decomposition of plant litter and thus nutrient recycling too.

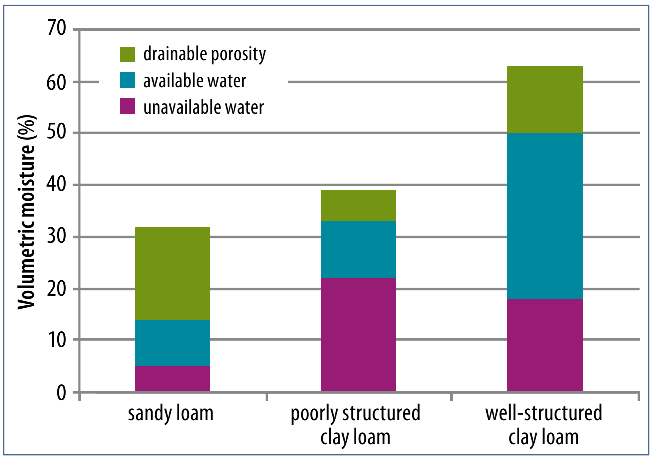
Flooding

The floodplains of Britain have been significantly affected by past river engineering and management. Flood defence barriers, embankments and drainage networks affect the flow, flooding and sedimentation patterns of floodplain meadows. Where inflow and outflow is disrupted by embankments, water may be slow to drain from meadows, causing excessive waterlogging. This can be a particular problem during summer flooding events, when the embankments may retain the water on the floodplain. Embankments can also reduce the frequency of flooding, leading to a reduction in nutrient inputs. Knowledge of the flow patterns and movement of floodwaters around a site is therefore very important (see Chapter 10).

Soil type

The rate of water movement through the soil is determined by two factors: the soil's hydraulic conductivity (which depends on physical structure) and the gradient of the water table across the site. Water flow in a poorly structured soil may be below 0.01 m/day as a result of small soil pores with little space for water movement. In well-structured soils it can be as high as 10 m/day, due to large pores that provide plenty of space for movement (Gowing, Tallowin *et al.* 2002; see also Figure 7.5).

Figure 7.5 The amount of water available to plant roots depends partly on the soil type.



Where well-structured alluvium overlies gravel beds there may be a ready supply of groundwater in summer, so stress due to soil drying is avoided because water is supplied to the meadow from the river. Sands and gravels can help to drain water away more quickly in winter, thereby reducing waterlogging stress (e.g. at North Meadow, Cricklade – see Figure 7.1). Conversely, where subsoils are clays with no link to a groundwater supply, both stresses are more likely to occur and greater care with the management of surface water is required to maintain a species-rich meadow, such as on the Ings of the River Derwent in East Yorkshire. More information on soils can be found in Chapter 5.

Managing water

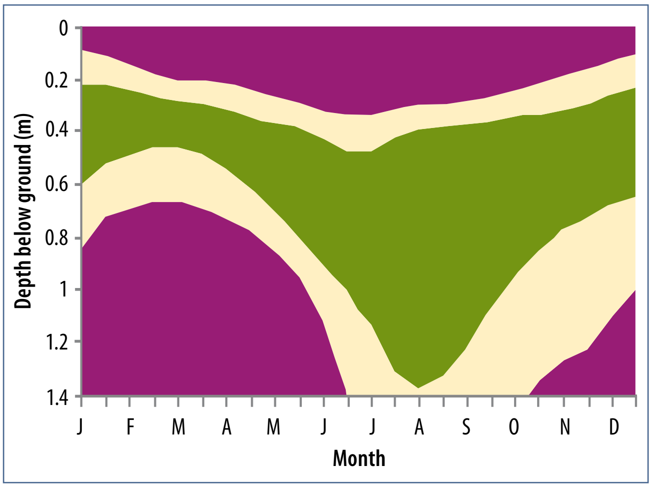
Floodplain meadows are often managed with the objective of maintaining, restoring or re-creating characteristic plant communities, primarily the Burnet floodplain meadow community (MG4). Figure 7.6 shows the typical soil-water tolerance of the Burnet floodplain meadow community (MG4). If the water regime falls outside the preferred range for this community (i.e. the violet area), plant communities of less botanical interest may develop, such as those dominated by large sedges, reed-grasses, or grasses typical of drier meadows.

Information on how to measure the water-table depth throughout the year can be found in Chapter 11. Potential management interventions to use if the water-table depths fall outside of the required range are described in Chapters 9 and 10.

Wider benefits of flooding on floodplain meadows

Floodplain meadows can help to reduce flood peaks to towns and cities located downstream by absorbing and storing water that would otherwise flood low-lying areas. Case Study 7.3 gives an example of how a major floodplain meadow, Clifton Ings and Rawcliffe Meadows SSSI contributes to reducing flooding in the city of York, as well as providing extensive recreation opportunities and supporting species-rich floodplain-meadow vegetation.

Figure 7.6 The soil-water level requirements for the Burnet floodplain meadow throughout the year as determined by Wheeler *et al*. (2004). Green – ideal water-table depth; cream – conditions under which the plant community could change if water-table depths persist in this zone; violet – water-table depths that will trigger a change in the plant community. Dipwell measurements of soil-water levels throughout the year over a number of years will reveal this information.



CASE STUDY 7.1
Wheldrake Ings, an alluvial floodplain meadow demonstrating how plant communities are situated in relation to topography and water levels

In lowland river systems with alluvial soils, floodwater that overtops the river bank normally drains towards a back ditch or internal drains, which collect and return the water to the river further downstream. The lowest-lying areas on the floodplain, which hold water for longest after a flood, experience the greatest sediment deposition. This is reflected in the different plant communities that develop according to the hydrology and nutrient status of the soil.

Figure 7.7 NVC map (2006) of communities at Wheldrake Ings showing positions of two monitoring transects. Numbers 1 and 2 and associated lines indicate the location of botanical transects recorded. Findings from each transect are shown in Figure 7.8. Yellow areas show existing species-rich MG4 grassland, grading to wetter communities. © Natural England 1000046223 (2006)

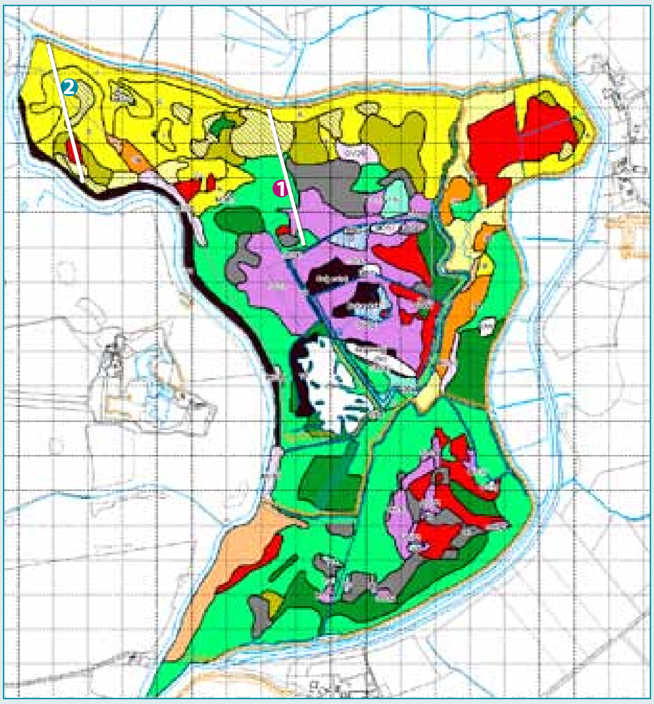
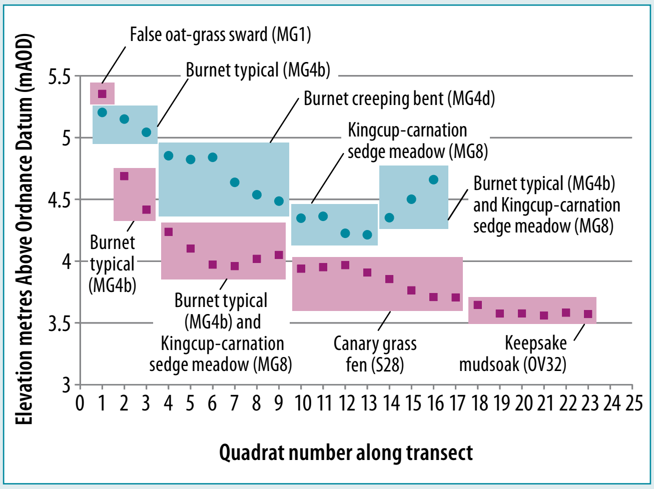


Figure 7.8 Elevation along two transect lines, transect 1 (■) and transect 2 (●) and principal vegetation communities along each transect.



On Wheldrake Ings (part of the Derwent Ings in Yorkshire), botanical monitoring was undertaken to explore the relationship between hydrology, topography and plant community. The monitoring focused on the main areas of Burnet floodplain meadow (MG4; see Figure 7.7). Here, flooding occurs from the river with drainage back to the river through a series of internal drains.

This research found that an elevation difference of only 1.7 m was sufficient to allow plant communities ranging from the terrestrial form of Amphibious bistort mat (A10) to Burnet floodplain meadow (MG4), Kingcup-carnation sedge meadow (MG8) and the dry False oat-grass sward (MG1) to flourish. Figure 7.8 shows the distribution of plant communities along the topographical gradient.

CASE STUDY 7.2

West Sedgemoor, Somerset – demonstrating how plant communities are situated in relation to topography and water levels

On peaty catchments, extensive areas of low-lying ground have been ditch-drained in historic times to turn wetlands into agricultural land. In these systems, water levels in the internal drainage ditches and the main river influence the water table across the site. Such sites are often subject to intensive water-level management. The Somerset Levels provide some of the best examples of ditch-drained, reclaimed peatlands where water levels are managed through internal ditch-level controls. A series of sluices and bunds allow the water to be held at different levels across the site, thus providing considerable variation in soil-water levels during the growing season. The variation in the ditch-water levels has been shown to influence the plant communities present; differences of less than 1.2 m result in a gradation from swamp and inundation communities capable of intensive management.

Vegetation communities are also affected by the interaction between ditch-water levels and past management. Where land has been cultivated in the past, fertility levels are enhanced and the structure of the peat can be lost. Areas with the same soil-moisture conditions can therefore support different plant communities depending on whether fertiliser has been applied in the past. A given ditch level may result in anoxic soil conditions in previously cultivated areas (because of the loss of soil structure), but not in uncultivated areas. Low-lying land of low fertility where the peat structure remains intact supports species-rich Kingcup-carnation sedge meadow (MG8) and Sedge lawn (MG14) vegetation whilst other areas of similar elevation that have been improved in the past support species-poor Foxtail plash (MG13; see Chapter 8).

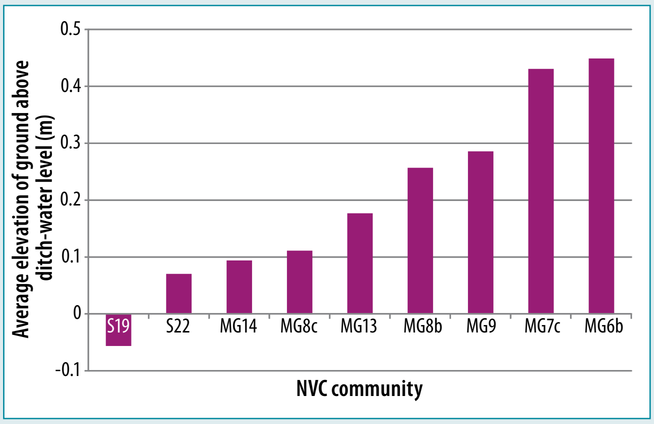


Figure 7.9 Field elevation relative to ditch-water level during the period March–May at West Sedgemoor, Somerset, 2003–2005. The plant communities are graded according to the elevation.

The wetter plant communities at West Sedgemoor, showing areas of species-rich Kingcup-carnation sedge meadow (MG8). © Mike Dodd

The drier plant communities at West Sedgemoor showing areas of Knapweed meadow (MG5) on the upper slopes of the reserve. © Harry Paget-Wilkes

CASE STUDY 7.3
Clifton Ings and Rawcliffe Meadows SSSI – washland and floodplain meadow

Clifton Ings and Rawcliffe Meadows are two adjacent sites which together were designated as an SSSI in 2013. The 56 ha SSSI supports Burnet floodplain meadow (MG4), Kingcup-carnation sedge meadow (MG8) and the critically endangered tansy beetle. Rawcliffe Meadows have been restored by the 'Friends of Rawcliffe Meadows' (FoRM)[28] who have carefully managed and developed the site since 1990. The whole area is also heavily used for recreational purposes, accommodating walkers and cyclists in significant numbers. The SSSI and a further non-designated grazing marsh to the north (Rawcliffe Ings) form part of an important controlled washland within the City of York, between the outer ring road and the City Walls. Rawcliffe Ings and Meadows are owned by the Environment Agency and in part managed by FoRM, whilst Clifton Ings are under multiple private ownership.

The flood-storage area, or washland, forms an essential part of York's flood defences. The natural floodplain at Clifton and Rawcliffe Ings was embanked 1979–1982 to increase storage capacity and to allow more controlled flooding via inflow and outflow sluices. With a water-storage capacity of around 2.3 million cubic metres, the washland reduces medium-range floods in the centre of York by 15 cm, enough to reduce the risk of flooding to many properties.

This site illustrates how a species-rich grassland can provide the important ecosystem benefit of flood-risk management, where the key to success is the active and well-informed management of the site. Floodwaters need to be released back to the river as soon as the flood peak is past, and the maintenance of the species-rich grassland is reliant on good communication and co-operation between all parties, and ongoing, sensitive management by the numerous groups responsible.

Figure 7.10 The location of Clifton Ings and Rawcliffe Meadows SSSI (red lines) and the washland (blue lines), which provides floodwater storage for the city of York. © Crown Copyright and Database Right [December 2015]. Ordnance Survey (Digimap Licence).

Many thanks to additional contributors Martin Fuller, Emma Leighton and Mick Phythian.

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[28] http://rawcliffemeadows.wordpress.com/

Burnet floodplain meadow (MG4) on Clifton Ings and Rawcliffe Meadows SSSI represents approximately 5% of the UK resource of this internationally important plant community. © Emma Rothero

Chapter 8
Plant communities of floodplain meadows

Hilary Wallace and Mike Prosser

The key plant communities of floodplain meadows are described here, including their distribution and environmental preferences. New accounts of Burnet floodplain meadow (MG4) and Kingcup-carnation sedge meadow (MG8) are given, with particular reference to their soil-water regimes and soil fertility. Two new grassland communities, Sedge lawn (MG14) and Cuckooflower grassland (MG15p), and a new sub-community of Ryegrass pasture (MG6) (Meadowsweet sub-community (MG6d)), are also described.

The presence of particular plant communities depends on the environmental conditions at the site. An understanding of these communities will reveal a great deal about the history, past management and underlying soil conditions of the site, which will help inform management. Floodplain-meadow communities range from relatively dry and species-rich grasslands through inundated wet grasslands to single-species swamps. Transitions to mire and ephemeral communities also occur and add to the overall diversity of the meadows. The key communities however are the grasslands. Two main grassland communities were described in the National Vegetation Classification (Rodwell 1992) and more recent work undertaken by the FMP[29] has expanded the known distribution of these communities and allowed the recognition of sub-communities defined by differences in water regime and soil fertility. This work has also resulted in the definition of two new communities, and identified a new sub-community, all of which can be found on floodplain meadows (see Table 8.1).

A number of different terms are used in the study of phytosociology. These are:

Constant – a species present in more than 60% of samples of a vegetation community or sub-community (recorded as IV or V in NVC tables)
Frequent – a species present in between 41 and 60% (recorded as III in NVC tables)
Occasional – a species present in between 21 and 40% (recorded as II in NVC tables)
Scarce – a species present in between 1 and 20% (recorded as I in NVC tables)
Preferential – a species that occurs at a higher frequency in one sub-community than in the community as a whole; and at a higher frequency than in any of the other sub-communities
Differential – a species that only occurs in one sub-community

Many of the plant species mentioned are illustrated in the FSC foldout guide to floodplain meadows (Gowing *et al*. 2010).

Community descriptions

Burnet floodplain meadow (MG4): *Alopecurus pratensis-Sanguisorba officinalis* grassland (see Figure 8.1)

Burnet floodplain meadow (MG4) is the typical floodplain-meadow vegetation community found on alluvial soils of intermediate fertility. Sites supporting this community are usually subject to traditional hay-meadow management. The species-rich sward can be quite varied, but is usually characterised by great burnet, common sorrel, meadow vetchling, red fescue and meadow buttercup. Dandelion, cuckooflower and, on some sites, snakeshead fritillary are often conspicuous in the spring. As the season progresses grasses become more prominent, but may be overtopped by tall herbs such as great burnet and meadowsweet later in the season. Species such as hawkbits, pepper-saxifrage, oxeye daisy and devil's-bit scabious add a splash of colour.

The Burnet floodplain meadow (MG4) as described in the NVC (Rodwell 1992) was based on only 22 samples, and has recently been studied in more detail[30]. Species data from 2,500 quadrats sampled across 48 sites have been used to differentiate four sub-communities that between them

Table 8.1 Floodplain-meadow plant communities described in this chapter[A].

Plant community	Description	Notes
Burnet floodplain meadow (MG4)	Classic, species-rich vegetation on drier soils of intermediate fertility	Expanded from existing NVC community
Ryegrass pasture (MG6)	This is a widely occurring community, but a species-rich variant occurs on damp soils of moderately high fertility	A new Meadowsweet sub-community (MG6d) added to the existing MG6 of the NVC
Kingcup-carnation sedge meadow (MG8)	Species-rich community on low-fertility sites where water table is constantly close to the surface	Expanded Kingcup-carnation sedge meadow (MG8) with four new sub-communities, one of which is close to the original MG8 community of the NVC
Foxtail plash (MG13)	Area of prolonged spring flooding and poor drainage	No change
Sedge lawn (MG14)	Occurs throughout floodplains, typically rich in marsh-marigold (kingcup) and small sedge species	An expanded version of the creeping bent-small sedge community originally described by Cox and Leach (1995). Now with two sub-communities
Cuckooflower grassland (MG15p) provisional	Species-poor community of damp sites with good restoration potential	Provisional new community with two sub-communities

A These communities are not all as in the original NVC of Rodwell (1992) as additional data has enabled recent revisions to be made. These communities should be considered as an update to the NVC.

29/30 http://www.floodplainmeadows.org.uk/about-meadows/wildlife/plant-communities

Figure 8.1 The distribution of all known sites for Burnet floodplain meadow (MG4) in England and Wales.

The Burnet floodplain meadow (MG4) at Yarnton, Oxfordshire. © Mike Dodd

represent the variability found within the community. These are summarised in Table 8.2, together with their differing hydrological and fertility tolerances (Figure 8.6). The complete distribution of known sites in England and Wales is given in Figure 8.1 (all distribution data discussed in this chapter covers England and Wales only).

Cock's-foot sub-community (MG4a) (see Figure 8.2)

The Cock's-foot sub-community is the most species-rich of the four sub-communities and is generally found where the water table remains low throughout the growing season and flooding is rare. Distinguishing species that are constant include cock's-foot and yellow oat-grass. Oxeye daisy, false oat-grass and yellow-rattle are frequent, while lady's bedstraw, goat's-beard, rough hawkbit, fairy flax and black medick (all occasional) are species indicative of summer drought that help differentiate the vegetation from that of the Typical sub-community. Meadow foxtail is found only sparsely and patchily in this sub-community.

The Cock's-foot sub-community is often present in quite small stands, generally on slightly drier ground than the Typical sub-community (see Table 8.2). It grades into Knapweed grassland (MG5) on drier ground and False oat-grass meadow (MG1) on less frequently cut areas and along unmanaged embankments. The most extensive stands are found at North Meadow and Clattinger Farm in Wiltshire, at Yarnton Mead near Oxford, and at Woodsides Meadow near Bicester.

Typical sub-community (MG4b) (see Figure 8.3)

The Typical sub-community, as its name implies, describes those stands closest in their species composition to the Burnet floodplain meadow community as a whole. However, stands of the Typical sub-community are less species-rich than those of the Cock's-foot sub-community, with on average 22 species per square metre, and there are no strongly preferential species. Spring inundation of the Typical sub-community is substantially less than that of both the Yorkshire fog and Creeping bent sub-communities but greater than the Cock's-foot sub-community.

Yorkshire fog sub-community (MG4c) (see Figure 8.4)

The Yorkshire fog sub-community has a high cover of grasses such as meadow foxtail, rough meadow-grass and creeping bent. It tends to be associated with sites which experience a high water table for longer periods during the growing

Table 8.2. Burnet floodplain meadow (MG4) sub-communities.

Vernacular name	NVC code and name	Species-richness	Key species	Flooding regime	Fertility * (available P kg/ha)	Similar European communities
Cock's-foot sub-community	MG4a *Dactylis glomerata* sub-community	Species-rich (25/m^2) especially in herbs	Yellow oat-grass, oxeye daisy, hogweed	Rarely flooded, relatively drought tolerant	Lowest fertility (P: 7.6±1.1)	Drier expressions of the Great burnet-pepper-saxifrage association in the Netherlands and northern Germany
Typical sub-community	MG4b Typical sub-community	Species-rich (22/m^2)	Field wood-rush, snakeshead fritillary	Occasionally flooded	Low fertility (P: 9.4±0.6)	Snakeshead fritillary-meadow foxtail community of Dutch floodplains, similar vegetation found in northern France
Yorkshire fog sub-community	MG4c *Holcus lanatus* sub-community	Species-poor (16/m^2), grass-dominated	Common couch	Frequently flooded	More fertile (P: 12.5±1.63)	Dutch Great burnet-pepper-saxifrage association Meadow foxtail-creeping buttercup-red clover meadow type described from Poland
Creeping bent sub-community	MG4d *Agrostis stolonifera* sub-community	Species-poor (15/m^2), dominated by flood-tolerant species	Creeping jenny, brown sedge	Long duration flooding	Highest fertility (P: 16.2±2.78)	Snakeshead fritillary-meadow foxtail-marsh-marigold community of the Netherlands and other meadows of northern France and Belgium

* Fertility status indicated by Olsen-extractable phosphorus (P) in the surface 10 cm of soil. Values are means ± one standard error.

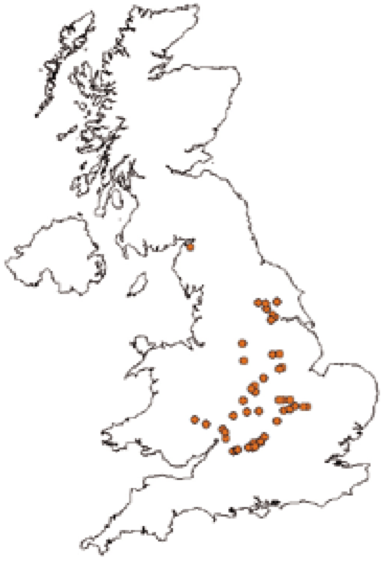

Figure 8.2 The distribution of all known sites in England and Wales for the Cock's-foot sub-community (MG4a) of Burnet floodplain meadow in the UK.

The Cock's foot sub-community (MG4a) of Burnet floodplain meadow at Yarnton Mead, Oxford. © Hilary Wallace

season than the two preceding sub-communities. It is the most widespread sub-community, and has been recorded from 35 of the 48 sites considered in the analysis. It lacks the species that are common in the Cock's-foot and Typical sub-communities, and does not have any strongly preferential species, although the frequency of common couch and tufted hair-grass is often higher, indicating less intensive management. It is less species-rich than the Cock's-foot and Typical sub-communities.

Creeping bent sub-community (MG4d) (see Figure 8.5)

The Creeping bent sub-community is the most species-poor. It tends to be associated with areas that experience prolonged inundation (which can also lead to higher soil fertility) and is especially characteristic of the Derwent Ings in Yorkshire. It is similar to the Yorkshire fog sub-community in having a high frequency and cover of meadow foxtail, but is distinguished from it by the high cover of creeping bent together with a suite of other preferential species typical of damp soil conditions, including cuckooflower, slender tufted-sedge, meadowsweet and creeping-jenny.

Sneezewort, tufted forget-me-not and marsh stitchwort are differential to this sub-community, although often only scarce or occasional in their frequency. Stands may grade into the newly described Cuckooflower grassland (MG15p) (see below).

Kingcup-carnation sedge meadow (MG8): *Cynosurus cristatus-Carex panicea-Caltha palustris* grassland (see Figure 8.7)

The MG8 Kingcup-carnation sedge meadow was not well-defined in the NVC (Rodwell *et al.* 2000) and no sub-communities were recognised. An analysis of plant data from 4,706 quadrats, carried out by the Floodplain Meadows Partnership[31], has extended the definition of this

Figure 8.3 The distribution of all known sites for the Typical sub-community (MG4b) of Burnet floodplain meadow in England and Wales.

The Typical sub-community (MG4b) of Burnet floodplain meadow at North Meadow, Cricklade. © Hilary Wallace

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31 http://www.floodplainmeadows.org.uk/about-meadows/wildlife/plant-communities

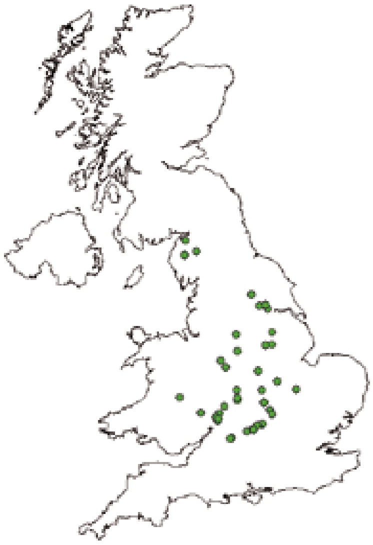


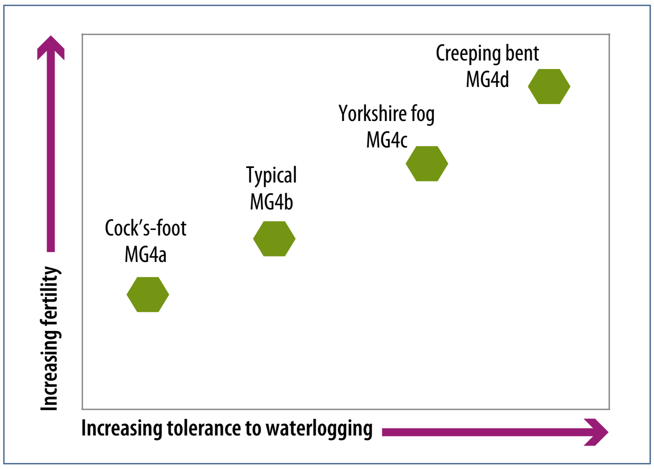
Figure 8.4 The distribution of all known sites in England and Wales for the Yorkshire fog sub-community (MG4c) of Burnet floodplain meadow in England and Wales.

Yorkshire fog sub-community (MG4c) of Burnet floodplain meadow at Clifton Ings, North Yorkshire. © Hilary Wallace

Figure 8.5 The distribution of all known sites for the Creeping bent sub-community (MG4d) of Burnet floodplain meadow in England and Wales.

The Creeping bent sub-community (MG4d) of Burnet floodplain meadow at Derwent Ings, Yorkshire. © Hilary Wallace

Figure 8.6 The relative positions of Burnet floodplain meadow sub-communities according to gradients in fertility and waterlogging.



community (and amended the name with the addition of carnation sedge). Four distinct sub-communities have been recognised. One of these, the Typical sub-community, relates closely to the original description of Kingcup-carnation sedge meadow (MG8). The floristic variation between the sub-communities relates more to soil fertility than hydrology (see Table 8.3).

Kingcup-carnation sedge meadow (MG8) generally occurs on less fertile soils than those supporting the Burnet floodplain meadow community. It is characteristic of sites where the water table is constantly close to the surface such that both soil-drying and waterlogging stresses are relatively slight. It is found on damp alluvial or peaty substrates and occasionally, as on the Somerset Levels, on sites where clay overlies peat. Although many sites supporting Kingcup-carnation sedge meadow (MG8) are cut for hay annually, the wetter peaty sites may be managed as permanent pasture, usually for cattle. It is not uncommon for management to alternate between a hay cut and cattle grazing, depending on soil conditions in the spring.

The high frequency of sedge species helps separate this vegetation from the drier Burnet floodplain meadow (MG4), with carnation sedge, glaucous sedge, common sedge and brown sedge all characteristic. Prominent grasses include Yorkshire fog, red fescue and crested dog's-tail. Tall and often colourful herbs help to separate the different sub-communities; the most notable are great burnet, common knapweed, devil's-bit scabious (MG8a), common meadow-rue and meadow thistle (MG8c) and, in the north, globeflower and marsh hawk's-beard (MG8d). In the spring, flowering marsh-marigold (kingcup) helps to mark out areas supporting this community.[32]

Burnet sub-community (MG8a) (see Figure 8.8)

This sub-community appears to be almost entirely confined to mineral soils and forms a link between Kingcup-carnation sedge meadow (MG8) and the damper end of Burnet floodplain meadow (MG4). This gradation is particularly well-developed on Mottey Meadows in Staffordshire. The sub-community is also a feature of the Oxford Meads, Long Herdon in Buckinghamshire, Poolhay Meadows in Worcestershire and Woodsides Meadow in Oxfordshire.

Figure 8.7 The distribution of all known sites for Kingcup-carnation sedge meadow (MG8) in England and Wales.

The Kingcup-carnation sedge meadow (MG8) at West Sedgemoor. © Hilary Wallace

Table 8.3 Kingcup-carnation sedge meadow (MG8) and Sedge lawn (MG14) sub-communities. Fertility values are mean Ellenberg 'N'* scores based on species composition. Limited data are also available for Olsen's extractable phosphorus (P).

Vernacular name	NVC code and name	Key species	Hydrology	Fertility	Similar European communities
Kingcup-carnation sedge meadow (MG8)					
Burnet sub-community	MG8a *Sanguisorba officinalis* sub-community	Common knapweed, devil's-bit scabious, sharp-flowered rush	Rarely flooded	Low (N=4.31, P=14 mg/kg^{-1})	None
Typical sub-community	MG8b Typical sub-community	Brown sedge, jointed rush, water avens, greater bird's-foot-trefoil	Occasionally flooded	Moderate (N=4.82, P=10 mg/kg^{-1})	Greater bird's-foot-trefoil sub-community of the Perennial ryegrass-crested dog's-tail community in the Netherlands
Common sedge-lesser spearwort sub-community	MG8c *Carex nigra-Ranunculus flammula* sub-community	Meadow thistle, marsh ragwort, brown bent	Highest water table, rarely dry	Lowest fertility (N=4.15, P=9 mg/kg^{-1})	Meadow foxtail-narrow-leaved water-dropwort community of Croatia Meadow thistle-purple moor-grass community from the Netherlands
Kingcup-daisy sub-community	MG8d *Caltha palustris-Bellis perennis* sub-community	Globeflower, marsh hawk's-beard, lady's-mantles, yellow-rattle	Driest of the units, very rarely flooded	Highest fertility (N=5.01)	None
Sedge lawn (MG14)					
Typical sub-community	MG14a Typical sub-community	Reed sweet-grass, tubular water-dropwort, common spike-rush	More flood tolerant	Both sub-communities have similar fertility levels (N=4.99)	Jointed rush sub-community of the Buttercup spp-Marsh ragwort community in the Netherlands
Sweet vernal-grass sub-community	MG14b *Anthoxanthum odoratum* sub-community	Meadow fescue, white clover, autumn hawkbit	On drier soils although still more flood tolerant than MG8 Kingcup-carnation sedge meadow and MG13 Foxtail plash	Mean Ellenberg (N=4.99)	Jointed rush sub-community of the Buttercup spp-Marsh ragwort community in the Netherlands

* Ellenberg (1988) indicator values reflect a species' tolerance to various environmental conditions. Ellenberg N is considered to be a general indicator of soil fertility; scores range from 1 (extremely infertile soil) through 5 (intermediate fertility) to a maximum of 9 (extremely rich areas, often with localised nutrient addition, e.g. cattle dunging areas, polluted rivers). Ellenberg scores allow inferences to be made about the ecological conditions pertaining at a site (Hill *et al.* 1999).

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[32] Note that the vernacular name for this community (after Rodwell, undated) includes kingcup *Caltha palustris*. Plant species nomenclature used here follows that of Stace (2010), and the more commonly used English name of marsh-marigold is used throughout the text for this species.

Figure 8.8 The distribution of all known sites for the Burnet sub-community (MG8a) of Kingcup-carnation sedge meadow in England and Wales.

Burnet sub-community (MG8a) of Kingcup-carnation sedge meadow at Mottey Meadows, Staffordshire. © Hilary Wallace

Stands of this sub-community are almost invariably cut for hay; this management reflects the position of the sub-community at the driest end of the hydrological gradient on which MG8 Kingcup-carnation sedge meadow occurs. It also tends to occupy sites of relatively low fertility.

The characteristic species of this sub-community are great burnet, common knapweed and, usually, sharp-flowered rush. Devil's-bit scabious, selfheal, common bird's-foot-trefoil, glaucous sedge and pepper-saxifrage are also frequent and the community constants (crested dog's-tail, carnation sedge, meadowsweet, red fescue, meadow buttercup, Yorkshire fog, sweet vernal-grass and ribwort plantain) are all well-represented. Meadow foxtail is poorly represented, as are some of the normal suite of MG8 Kingcup-carnation sedge meadow species, notably marsh ragwort, marsh thistle and common sedge.

Typical sub-community (MG8b) (see Figure 8.9)

Unlike the Burnet sub-community, the Typical sub-community tends to be more frequent on peaty or humic substrates and has a higher frequency of more flood-tolerant species. Stands of this community are more commonly managed as permanent pasture, usually cattle-grazed, than those of the other sub-communities. Although examples are widespread across England and Wales, there are notable concentrations on the floodplains of the Avon, Itchen and Test (Hampshire/Dorset) and in East Anglia, where this vegetation frequently grades into Blunt-flowered rush-pasture (M22) (see Appendix) as seen at Marston Marshes. It occurs on more fertile soils than the Burnet sub-community.

Like many sub-communities labelled 'Typical' this sub-community lacks strong preferentials, although brown

Figure 8.9 The distribution of all known sites for the Typical sub-community (MG8b) of Kingcup-carnation sedge meadow in England and Wales.

Typical sub-community (MG8b) of Kingcup-carnation sedge meadow at Baswich, Staffordshire. © Hilary Wallace sedge, jointed rush, water avens, greater bird's-foot-trefoil and fen bedstraw all occur frequently.

Common sedge-lesser spearwort sub-community (MG8c) (see Figure 8.10)

First described from West Sedgemoor on the Somerset Levels as the carnation sedge-meadow thistle variant of Kingcup-carnation sedge meadow (MG8) (Wallace and Prosser 2002), recent work has shown the geographic range of this vegetation to extend beyond its main locus in Somerset into East Anglia, the Midlands and Wales, with a single occurrence identified in Yorkshire at Thornton and Melbourne Ings[33]. This sub-community develops under conditions of low fertility compared to the other sub-communities and occupies the wettest soil profiles, being most prevalent on peat substrates.

It appears to be more often cut for hay than used as pasture, even though the typically low-growing sedge lawn offers only a modest hay crop. Red fescue is found only very sparsely, as are other mesotrophic grasses such as perennial rye-grass and rough meadow-grass. These are replaced by the lower-growing brown bent and heath-grass.

Although tall herbs such as meadow thistle, common meadow-rue and marsh ragwort are frequent, several low-growing species are characteristic including lesser spearwort, marsh pennywort, common yellow-sedge and rough hawkbit. A species of local interest found in this community is marsh arrowgrass.

Kingcup-daisy sub-community (MG8d) (see Figure 8.11)

This is a northern expression of Kingcup-carnation sedge meadow (MG8) usually associated with smaller rivers and streams rather than with extensive floodplains. Many of the stands extend upslope from the watercourse in zones which are rarely flooded. Examples are known from valleys within the Yorkshire Dales (Alcock 1982), Durham Dales, Teesdale, Baldersdale (Prosser 1990b), Weardale (Wiggington 1988), South Northumberland (Loring 1983), West Allendale and South Tynedale (Prosser 1990a) and Cumbria (NCC 1980).

The vegetation tends to be associated with fertile substrates, but contains a lower proportion of flood-tolerant species than do the other sub-communities. Species typical of drier neutral grasslands reach their highest frequency in this sub-community, with red clover, white clover, common sorrel, daisy, common mouse-ear and perennial rye-grass all constant. Marsh-marigold (kingcup) reaches its highest frequency in the sward, and species with a predominantly northern distribution feature prominently – diagnostic species include globeflower, marsh hawk's-beard and species of lady's-mantle. In some seasons yellow-rattle becomes very prominent. Unlike the other sub-communities both meadowsweet and carnation sedge occur only sparsely. On the majority of sites where management is known, it tends to be the typical floodplain-meadow regime of hay cutting followed by aftermath grazing. This sub-community is often associated with Northern hay-meadow (MG3), but is clearly delineated from it. Northern hay-meadow is characterised by a suite of drought-tolerant species including wood crane's-bill, pignut, common bent, bulbous buttercup and a lady's-mantle. Carnation sedge, marsh-marigold (kingcup) and water avens are only occasionally recorded in Northern hay-meadow (MG3) within which they are generally scarce.

Sedge Lawn (MG14): *Carex nigra-Agrostis stolonifera-Senecio aquaticus* grassland

Sedge lawn (MG14) was not included in the original description of grassland communities (Rodwell 1992). It was first described on the Somerset Levels (Cox and Leach 1995) and appears to be widespread and abundant in that area (Prosser and Wallace 1996) and in Hampshire and Dorset (B. Edwards and I. Ralphs pers. comm). It occurs throughout floodplains, occupying some of the most frequently inundated areas. It sometimes resembles species-rich Foxtail plash (MG13), but is typically rich in marsh-marigold (kingcup) and small sedge species. Common sedge, creeping bent, creeping buttercup and cuckooflower are the main community constants. Substrates supporting this community are generally much less fertile than those of Foxtail plash (MG13), but more fertile than those of Kingcup-carnation sedge meadow (MG8). It is probably derived from stands of the sedge-rich Common sedge-lesser spearwort

Figure 8.10 The distribution of all known sites for the common sedge-lesser spearwort sub-community (MG8c) of Kingcup-carnation sedge meadow in England and Wales.

The common sedge-lesser spearwort sub-community (MG8c) of Kingcup-carnation sedge meadow at West Sedgemoor, Somerset. © Hilary Wallace

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[33] http://www.floodplainmeadows.org.uk/about-meadows/wildlife/plant-communities

Figure 8.11 The distribution of all known sites for the Kingcup-daisy sub-community (MG8d) of Kingcup-carnation sedge meadow in England and Wales.

The Kingcup-daisy sub-community (MG8d) of Kingcup-carnation sedge meadow at Ashes Meadow, Yorkshire. © Hilary Wallace

Figure 8.12 The distribution of all known sites for Sedge lawn Typical sub-community (MG14a) in England and Wales.

Sedge lawn (MG14) at West Sedgemoor, Somerset Levels. © Hilary Wallace

sub-community (MG8c) that are subject to prolonged inundation. It is unusual among floodplain-meadow communities in that many stands are on soils where clay overlies peat.

Sedge lawn (MG14) may be distinguished from Kingcup-carnation sedge meadow (MG8) (see Table 8.3) by:

- much higher frequencies and cover of creeping bent, creeping buttercup, amphibious bistort and marsh ragwort;
- much lower frequencies of meadowsweet, red clover, ribwort plantain, Yorkshire fog and red fescue; and
- the absence of timothy and quaking-grass.

The Typical sub-community (MG14a) (see Figure 8.12)

This sub-community is characterised by a predominance of flood-tolerant species including floating sweet-grass, common spike-rush, tubular water-dropwort and amphibious bistort. It is often found on sites with a greater propensity to summer flooding than the Sweet vernal-grass sub-community (MG14b), and most closely resembles the community initially described by Cox and Leach (1995). It is managed either for hay or as pasture, probably depending on annual variation in soil-water tables.

Sweet vernal-grass sub-community (MG14b) (see Figure 8.13)

The Sweet-vernal grass sub-community (MG14b) occupies generally drier sites of similar fertility to the Typical subcommunity. In addition to sweet vernal-grass, other characteristic meadow species are more frequent than in the Typical sub-community (MG13a), including crested dog's-tail, perennial rye-grass, meadow foxtail and meadow fescue together with white clover, meadow buttercup and autumn hawkbit. The sward is bulkier and taller and has a higher ratio of grasses to herbs than the Typical sub-community, and stands are typically cut for hay rather than used as pasture.

Figure 8.13 The distribution of all known sites for the Sweet vernal-grass sub-community (MG14b) of Sedge lawn in England and Wales.

Sweet vernal-grass sub-community (MG14b) of Sedge lawn at West Sedgemoor, Somerset. © Mike Dodd

Meadowsweet sub-community (MG6d) of MG6 Ryegrass pasture: (*Lolium perenne-Cynosurus cristatus* grassland) (see Figure 8.14)

Ryegrass pasture (MG6) is semi-improved and often regarded as being of little conservation value, although some stands of the Sweet vernal-grass sub-community (MG6b) are quite species-rich, whilst the more calcareous Yellow oat-grass sub-community (MG6c) can also have many species of interest. Within floodplains, a new species-rich sub-community has been identified and is characterised by frequent meadowsweet. This sub-community (MG6d) is probably derived from Kingcup-carnation sedge meadow (MG8) on damp soils following agricultural improvement. In some situations there are clear affinities between this sub-community and mires rich in meadowsweet such as Meadowsweet fen (M27) and Iris fen (M28) (Rodwell 1992).

The Meadowsweet sub-community (MG6d) is a cosmopolitan vegetation type that occurs on soils of moderately high fertility that are less fertile than those supporting Ryegrass and other leys (MG7) and Foxtail plash (MG13). This sub-community occupies some of the driest areas of the floodplain that are rarely flooded, possibly due to local drainage. It tends to be most frequent on deep peat profiles but it can also be found on alluvial soils, although rarely on clay over peat. The relatively dry soil conditions mean that most sites supporting this vegetation are managed as hay meadow rather than pasture.

Crested dog's-tail, perennial rye-grass, Yorkshire fog, red fescue, white clover and common mouse-ear (the Ryegrass pasture (MG6) community constants) are all very well-represented in the Meadowsweet sub-community, as are meadow buttercup, common sorrel and ribwort plantain. Apart from meadowsweet, the most prominent identifiers of the sub-community are red clover, cuckooflower, creeping buttercup and timothy.

With appropriate water-level management, cutting and cessation of fertiliser application, these stands have great potential for reversion to the more species-rich floodplain-meadow communities from which they were derived, most frequently Kingcup-carnation sedge meadow (MG8).

Cuckooflower grassland (MG15p): *Alopecurus pratensis-Poa trivialis-Cardamine pratensis* grassland (provisional) (see Figure 8.15 and Table 8.4)

This is a newly identified community that includes floodplain-meadow swards strongly dominated by the robust grasses meadow foxtail and meadow fescue, often with smooth brome, timothy and some tufted hair-grass. Cuckooflower and creeping buttercup are constant species.

Table 8.4 Meadowsweet sub-community (MG6d) of Ryegrass pasture and Cuckooflower grassland (MG15p) sub-communities.

Vernacular name	NVC code and name	Key species	Hydrology	Fertility	Similar European communities
Ryegrass pasture (MG6)					
Meadowsweet sub-community	MG6d *Filipendula ulmaria* sub-community	Creeping buttercup, red clover, timothy	Rarely flooded	High fertility (mean Ellenberg* N=5.2)	Rush-crested dog's-tail community of Sougnez (1957) from Belgium
Cuckooflower grassland (MG15p)					
Creeping bent sub-community	MG15pa *Agrostis stolonifera* sub-community	Marsh foxtail, curled dock, narrow-leaved water-dropwort, common couch	Occasionally flooded	Very high fertility (mean Ellenberg N=5.9)	Snakeshead fritillary-meadow foxtail grassland, Typical sub-community of the Netherlands
Rygrass-meadow buttercup sub-community	MG15pb *Lolium perenne-Ranunculus acris* sub-community	Sweet vernal-grass, common sorrel, Yorkshire fog	Infrequently flooded	High fertility (mean Ellenberg N=5.5)	Snakeshead fritillary-meadow foxtail grassland, Crested dog's-tail sub-community from the Netherlands

* Ellenberg (1988) indicator values reflect a species' tolerance to various environmental conditions. Ellenberg N is considered to be a general indicator of soil fertility; scores range from 1 (extremely infertile soil) through 5 (intermediate fertility) to a maximum of 9 (extremely rich areas, often with localised nutrient addition, e.g. cattle dunging areas, polluted rivers). Ellenberg scores allow inferences to be made about the ecological conditions pertaining at a site (Hill *et al.* 1999).

Figure 8.14 The distribution of all known sites for the Meadowsweet sub-community of Ryegrass pasture (MG6d) in England and Wales.

Meadowsweet sub-community (MG6d) at Westhay Moor, Somerset. © Hilary Wallace

This kind of vegetation was previously subsumed among a compendious group of mostly species-poor grasslands (Rye-grass and other leys (MG7)) similar to the Perennial rye-grass-meadow foxtail-meadow-fescue sub-community (MG7c). It can now be seen as a new community which sits between Burnet floodplain meadow (MG4) and Kingcup-carnation sedge meadow (MG8) on the hydrological gradient, but is generally present on more fertile soils. In the analysis[34] the definition of this community requires further study, so is considered in this handbook as a *provisional* new community.

Analysis of data from 50 sites has suggested that two sub-communities can be recognised. Both favour mineral soils and are typically cut rather than grazed as pasture. Soils are fertile with mean Ellenberg N scores >5, but their moisture tolerances are quite different. The presence, albeit at low frequency, of pepper-saxifrage, common knapweed, brown bent, creeping-jenny and sometimes great burnet indicate the communities' potential for restoration to Burnet floodplain meadow (MG4).

Creeping bent sub-community (MG15pa)

In addition to creeping bent, this sub-community has marsh foxtail, common couch, curled dock, narrow-leaved water-dropwort and reed canary-grass as preferential species. Some species more commonly associated with Kingcup-carnation sedge meadow (MG8) also occur occasionally, including creeping-jenny, marsh-marigold (kingcup), brown sedge and slender tufted-sedge. This sub-community is a prominent component of the vegetation of such diverse sites as Clifton Ings (Yorkshire), Upton Ham (Worcestershire), Upham Meadow (Gloucestershire), Ashleworth Ham (Gloucestershire) and the more inundation-prone parts of Portholme (Cambridgeshire). It occupies soils frequently inundated for

Figure 8.15 The distribution of all known sites for Cuckooflower grassland (MG15p) in England and Wales.

Cuckooflower grassland (MG15p) at Hampton Meadow, Herefordshire. © Hilary Wallace

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[34] http://www.floodplainmeadows.org.uk/about-meadows/wildlife/plant-communities

long periods, placing it hydrologically closer to Kingcup-carnation sedge meadow (MG8) than Burnet floodplain meadow, which it can replace, at least temporarily, following periods of prolonged spring and summer flooding. It also has affinities with Foxtail plash (MG13) inundation grassland.

Ryegrass-meadow buttercup sub-community (MG15pb)

This sub-community is more common than the Creeping bent sub-community (MG15pa) and is heavily grass-dominated with perennial rye-grass, sweet vernal-grass, crested dog's-tail, Yorkshire fog, meadow fescue and timothy all constant. In addition to meadow buttercup, meadowsweet is often prominent and species typical of Burnet floodplain meadow (MG4) such as pepper-saxifrage and great burnet occur occasionally. This sub-community appears to be more stable than the Creeping bent sub-community (MG15pa) and forms a long-term component of the floodplain-meadow assemblage on drier soils. It is particularly well-developed on the Somerset Levels, in the Midlands on Lugg Meadow in Herefordshire and to the north on East Cottingwith Ings in Yorkshire. Stands are relatively species-rich, averaging up to 17.3 species/m^2.

Foxtail plash (MG13): *Agrostis stolonifera-Alopecurus geniculatus* grassland

Other plant communities often occur on floodplain meadows in areas where there is prolonged spring flooding, and form an integral part of the natural hydrological sequence. In particular, Foxtail plash (MG13) is often associated with areas of poor drainage resulting from soil compaction on more fertile floodplains. Common along trackways, it is also found in extensive patches where drainage has failed in semi-improved meadows and pastures, for example, on the Ouse Washes and Somerset Levels (Prosser and Wallace 1996; Wallace and Prosser 2007). It is species-poor and dominated by grasses. Creeping bent, marsh foxtail and rough meadow-grass are all prominent, sometimes with frequent creeping buttercup and curled dock. Although Foxtail plash (MG13) has little botanical conservation value, it is an important component of grazing marshes for wintering wildfowl and waders in the spring.

Drivers of change in plant communities

Soil moisture is the main driver of separation between the sub-communities of Burnet floodplain meadow (MG4), which all occur on more fertile soils than Kingcup-carnation sedge meadow (MG8).

Within Kingcup-carnation sedge meadow (MG8), hydrological variation is small and fertility is the main factor causing differences in species composition (see Figure 8.16).

Descriptions of other grassland communities found on floodplains, including Foxtail grassland (MG7d), can be found in the Appendix.

Mires, swamps and ephemeral communities

A number of other plant community types are also found on floodplain meadows, including mires, swamps and ephemeral communities. More details on the description of these communities can also be found in the Appendix.

Plant communities and environmental factors

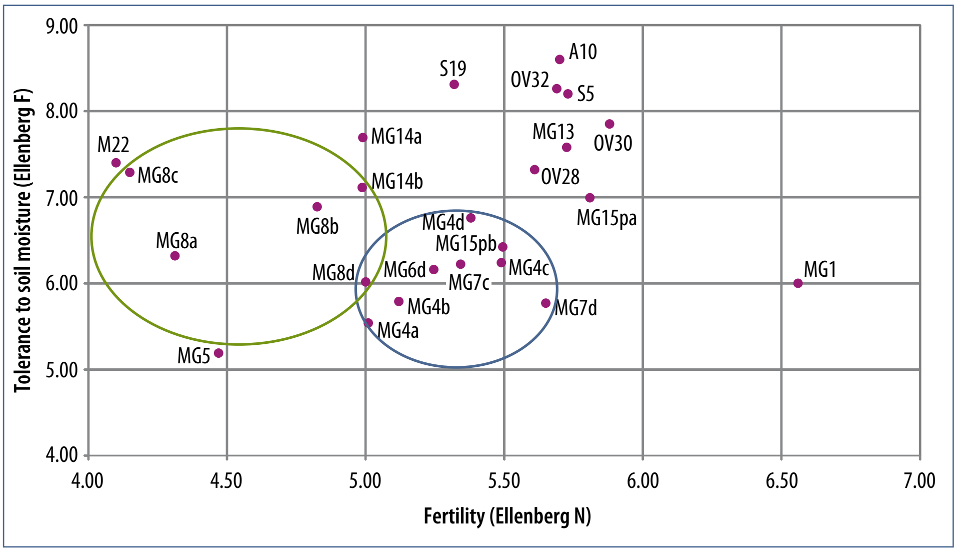
The key factors influencing plant-community distribution and composition on floodplain meadows are the availability of water during the growing season (see Chapter 7) and soil fertility (see Chapter 6). Although floodplain-meadow communities separate primarily along a hydrological gradient, species composition within communities is strongly influenced by soil fertility, soil type and also management. An important feature of floodplain meadows is that the distribution and extent of communities is not static – variations in the extent of flooding from year to year can result in annual shifts between inundation communities and also between these and more stable grasslands and swamps. Boundaries between the sub-communities of Burnet floodplain meadow (MG4) and Kingcup-carnation sedge meadow (MG8) can also shift considerably over periods of two to five years (Gowing *et al.* 2005). Within a site, small variations

Foxtail plash (MG13) at Wheldrake Ings Yorkshire. © Hilary Wallace in elevation, which influences depth to the water table, influence the distribution of plant communities; height differences of less than half a metre may allow the complete sequence from aquatic to dry grassland communities to occur.

The distribution of plant species, and so the development of different communities, is predominantly influenced by the length of time soils are waterlogged, especially during spring and summer months. Figure 8.16 shows the interplay between waterlogging and fertility in terms of community type. The underlying data were obtained through the intensive monitoring of soil-water levels on 18 sites using dipwells and the development of hydrological models to characterise the water-table heights at each sample position over a number of years (Gowing *et al.* 1998; Gowing, Lawson *et al.* 2002).

The mechanisms by which water reaches floodplain plant communities on different types of site are described in Chapter 7. Figure 8.17 illustrates the relative positions of the key plant communities within the floodplain and schematically shows how water is supplied to these communities.

Figure 8.16 The distribution of communities on floodplain meadows in relation to Ellenberg's values for fertility and waterlogging. Increasing values refer to increasing fertility and increased waterlogging. The numbers are relative values not real measurements.



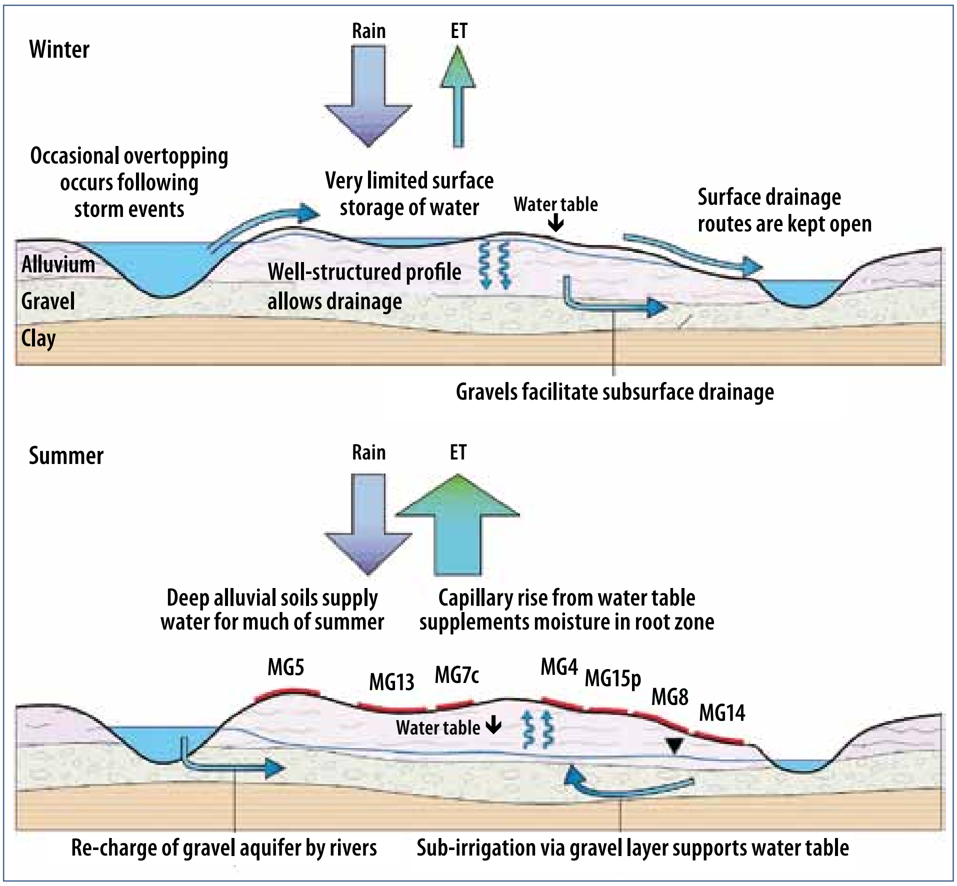
Ellenberg values

Ellenberg (1988) indicator values reflect a species' tolerance to various environmental conditions. They allow inferences to be made about the ecological conditions at a site (Hill *et al.* 1999).

Ellenberg F indicates moisture tolerance; scores range from 1 (soil regularly dries out), to a maximum of 12 (permanently submerged). Those with a score above 6 are tolerant of some waterlogging.

Ellenberg N is a general indicator of soil fertility. Scores range from 1 (extremely infertile), to a maximum of 9 (extremely fertile).

Figure 8.17 A schematic representation of the hydrological context of plant communities discussed in this chapter (adapted from Wheeler *et al.* 2004).



Chapter 9
Management

Clare Lawson

Appropriate management is essential for the maintenance of species-rich floodplain meadows. This chapter describes ideal management practices, identifies common problems and perceived conflicts of interest, discusses how to identify issues with hydrology and nutrients, and suggests solutions. Case studies provide examples of historic management, current good practice and impacts from changing management.

Objectives

The key conservation objective for species-rich floodplain meadows is to maintain or improve these plant communities while maintaining and enhancing populations of other groups (for example on some sites breeding birds are of particular interest) and ensuring a good quality hay crop. Typical management objectives to achieve these aims are:

- an annual hay cut in late June or early July;
- livestock grazing to remove the re-growth of grass from August through to early spring, or until the site becomes too wet;
- management of hedgerows to prevent encroachment of scrub;
- maintenance of grazing infrastructure such as fencing, stock handling and drinking points;
- control of weeds or undesirable species such as ragwort, sedges and creeping thistle; and
- maintenance of ditches, gutters and surface drains.

The historical management pattern of a site is key to determining specific management objectives, and it is important to talk to those who managed the system previously if at all possible. The plant community and associated fauna will have evolved within this pattern and should be retained (although restoration measures may be needed if historical management has lapsed). Historical management is not always recorded or known, in which case standard management objectives such as those outlined above should be considered.

Key management practices

The majority of floodplain meadows are cut for hay and then grazed with livestock. The vegetation is allowed to grow up in the spring, and is cut in late June/early July. The aftermath (re-growth of vegetation following the hay cut), is then grazed by livestock from August/September until the ground becomes too wet in the autumn or winter. In some cases, livestock return to the meadow in the early spring until it is shut up for hay in March/April.

Drainage is also an important part of floodplain-meadow management, and many sites include a network of ditches that drain into the river or back channel plus surface drains or 'grips'. This allows water to drain away after a flood so that it is not retained for too long, and for water to rise with the water level in the ditches and river, so the meadow is often kept moist.

How important is an annual seed set?

Most floodplain-meadow plant species are long-lived perennials and do not need to set seed every year. Of the many vascular species commonly found on floodplain meadows supporting Burnet floodplain meadow (MG4) and Kingcup-carnation sedge meadow (MG8) communities, only six are annuals (see Table 9.1).

In addition, mouse-ear and goat's-beard, though normally perennials, can behave as annuals, whilst tufted forget-me-not, normally biennial, can also function as an annual. The annual species typically ripen their seed before mid June. The other species do not rely on regular seeding to sustain their populations.

Table 9.1 Annual plants of floodplain-meadow communities.

Fairy flax	*Linum catharticum*
Lesser trefoil	*Trifolium dubium*
Yellow-rattle	*Rhinanthus minor*
Smooth brome	*Bromus racemosus*
Meadow brome	*Bromus commutatus*
Soft brome	*Bromus hordeaceus*

Meadow brome is an annual typical of floodplain meadows.
© Mike Dodd

Hay making

Hay making removes the biomass and prevents the accumulation of nutrients that would otherwise result in a less diverse sward, unlike in a continually grazed sward (i.e. a pasture) where the nutrients are simply recycled within the system rather than removed.

Hay-cutting regime

Hay making involves cutting the sward and allowing it to dry before removing and storing it for use in the winter. Hay making is dependent on dry weather and is quite labour intensive. The mown hay usually needs to be turned at least twice before it is sufficiently dry and then 'rowed up' for baling (unlike silage which is baled while still moist).

Traditionally, hay making on floodplain meadows started around Midsummer Day (24 June) or even earlier. Cutting by hand meant that the process was relatively slow, with some sites taking several weeks to cut. Cutting later than mid July where nutrient enrichment is an issue is not recommended as a regular practice. Cutting hay just as it begins to set seed removes the maximum amount of nutrients from the system and creates hay with a high nutritional value. The nutrient content lowers as seed is dropped and the plant returns nutrients to the base of the plant where it is stored.

Traditional hay cutting using scythes was slow compared to modern, mechanised hay making. The slower pace, together with the system of hay lots traditionally used on some sites (see Chapter 3), meant that cutting was more likely to be staggered across a floodplain-meadow system. Some of the botanical diversity found in traditionally managed floodplain meadows may be due to these differences in cutting times, and may be reduced by more homogenous regimes. Staggering cutting dates within a season also provides refuges for birds and invertebrates – see 'Management for wildlife' below. Changing cutting patterns and timings between years can also help. In any case, the exact timing of a hay cut may vary each year according to the weather conditions.

Grazing

Grazing animals affect floodplain-meadow vegetation as they graze selectively, preferring plants higher in nitrogen, phosphorus and gross energy (McDonald 2007a). These plants tend to be more vigorous, so grazing can result in an increase in species diversity by preventing bulky species from becoming dominant and creating space for less competitive species.

Grazing animals also alter floodplain-meadow plant communities through trampling and dunging (Crofts and Jefferson 1999). Trampling creates bare ground, exposing buried seed and providing suitable niches for seeds to germinate. This is particularly important for annual species such as yellow-rattle. Dunging returns some of the nutrients removed by grazing and, because animal dung and urine are not spread uniformly across a meadow, creates a patchy sward with structural diversity. More information about nutrient cycling in floodplain meadows can be found in Chapter 6.

A timely hay cut

The requirement for a timely cut is a particular feature of floodplain meadows because they rely so heavily on hay removal for maintenance of their nutrient balance.

All meadows with an active flooding regime are subject to increases in their nutrient status and the resultant variation in the plant community is part of the natural cycle. On a typical floodplain, where the meadows are flooded with sediment-laden river water at least once per decade, and traditional hay cuts are taken in midsummer each year, there may be no need to manage nutrient budgets. Many floodplain meadows have existed in balance for hundreds of years without any direct interventions regarding their nutrient status. Conversely, following a prolonged period (e.g. 10–20 years) without a flood event, or where a floodplain meadow has become disconnected from the river, the soil nutrients may become so low, or the surface soil sufficiently acidic, that some of the most typical species begin to decline.

It is often only where the traditional system has been disrupted that management of nutrients might be needed.

However, the decision about when to cut hay is not simple, and includes factors such as the weather, the condition of the sward and the presence of ground-nesting birds. For example, in a wet year, it may be necessary to wait for the ground to dry to avoid compacting the soil. Where bulky sedges or grasses have become dominant, an early cut or two cuts in a year is desirable if conditions allow. However, if ground-nesting birds are present, it may be necessary to defer the cut until the chicks have fledged (see 'Management for wildlife' below).

Sediment deposited at North Meadow after ten months of flooding. Periodically, such as following a period of repeated flood events, floodplain-meadow soils will become more nutrient rich than is optimal for a species-rich community and the larger grass species will dominate for a few years. Consistent and timely hay cutting in the following years will allow a return to a species-rich floodplain meadow. © Mike Dodd

Basing decisions on the quality of the hay crop for livestock (as was the traditional practice of farmers over the generations) is perhaps the best way of ensuring the conservation of a diverse plant community. More information can be found in the Floodplain Meadows Partnership article on cutting[35].

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[35] http://www.floodplainmeadows.org.uk/sites/www.floodplainmeadows.org.uk/files/files/Cutting%20Article.pdf

Why both graze and mow?

Historically, floodplain meadows were both mown for hay and grazed because this allowed the production of vital winter feed while maximising grazing opportunities. The combination of grazing and mowing increases species diversity (and creates a lovely floral display): hay making removes nutrients and allows plants to flower and sometimes set seed during the period the meadow is shut off from grazing animals, and aftermath grazing creates more diversity by providing areas of open soil for seeds to set into and reducing the dominance of bulky species.

The plant community created through these management activities, combined with a flooding regime, produces a distinctive plant community that is different from floodplain grassland managed as pasture. Switching to management as permanent pasture results in a shift in species composition, with a decline in tall perennials and the loss of early-flowering species that need to set seed to persist, such as yellow-rattle.

Stocking densities

There is very little recorded information on the stocking densities that floodplain meadows supported in the past. Modern-day stocking levels in the autumn for aftermath grazing range from 0.5 to 2.5 livestock units (LU) per ha (Gowing, Tallowin *et al.* 2002). Suitable stock densities depend on site-specific conditions and objectives – a key objective should be to avoid poaching.

Agri-environment scheme prescriptions are based around achieving indicators of success (e.g. sward height) rather than the means of getting there, and are adapted for individual sites. For example, for maintaining species-rich grassland, an indicator of success may be a sward height of around 2–8 cm in October, while for wet grassland suitable for breeding waders it may be around 5–15 cm in November. There may however be a restriction of around 0.75 LU/ha between April and the end of May for sites where spring grazing occurs and that have breeding waders, to reduce the chance of trampling eggs or chicks.

Grazing regime

The type of animals used, the stocking density and the timing of grazing are all important factors to consider (note that type of animal includes species, breed, age, sex and experience).

Body size is important: smaller animals select higher quality food as they need more energy relative to their body size (Rook *et al.* 2004). Species of grazing animal is also relevant; cattle curl their tongue around the vegetation and tear away plants leaving tufts of un-grazed vegetation and short grazed areas, while sheep are more selective feeders than cattle and eat the top part of the plant while they move across the grassland creating a more homogeneous structure in the vegetation (McDonald 2007a). Horses are able to graze much closer to the ground than both cattle and sheep and need to graze for a much longer period of time due to the difference in digestive physiology (Rook *et al.* 2004).

If horses are grazing a site, latrine areas will need management to prevent the localised build-up of nutrients and weed species such as docks and thistles (e.g. Gibson 1997). A long-term restoration study (see Case Study 10.11, Chapter 10) has shown that aftermath grazing with cows results in a greater plant and invertebrate diversity (McDonald 2011).

Timing of grazing

The timing of grazing is important (Crofts and Jefferson 1999). Spring-time grazing has the most direct impact on the growth of plants, as this is when leaf production is at its greatest. Provided a hay cut is going to be taken, grazing is not recommended beyond mid April in lowland meadows to allow plants to grow and flower. Where there are breeding waders, this may need to be earlier. Spring grazing intensity should not be too high or this may have a detrimental impact on the plant community composition. Aim for an average sward height of no less than 5–6 cm.

Autumn grazing has a significant impact as it can decrease the amount of food that plants are able to store over winter, reducing their vigour the following season. The date that grazing animals are removed will depend on the wetness of the site, but they should be removed promptly once conditions become too wet, and before poaching occurs, to avoid the detrimental impacts of compaction, more likely in wet conditions (see Chapter 5).

Wheldrake Ings, Yorkshire. Historically, cattle, sheep and horses have been used to graze the aftermath of floodplain meadows. On many floodplain meadows grazing by traditional stock no longer takes place. © Mike Dodd

Adaptations to grazing and mowing

Meadow plants are adapted to grazing and mowing, and are able to re-grow afterwards. Many meadow species are long-lived perennials and do not need to produce seed every year to survive (Duffey *et al.* 1974).

Devil's-bit scabious. There is some evidence to suggest that populations of plants in floodplain meadows such as devil's-bit scabious and common knapweed, flower and seed earlier than the same species in pastures, presumably because centuries of hay making have resulted in selection for earlier flowering (Jefferson 1997). © Mike Dodd

Ditches and drainage

Although able to tolerate some flooding, most floodplain-meadow vegetation cannot survive prolonged waterlogging, particularly in summer. For example, the Burnet floodplain meadow (MG4) plant community is intolerant of long periods of waterlogging resulting from flooding or from rainfall Gowing, Lawson *et al.* (2002). Where drainage is impeded, succession to other vegetation types, such as Tufted hair-grass pasture (MG9), Silverweed flood pasture (MG11) and Foxtail plash (MG13) may occur (see Chapter 8).

It is very important that the surface water inundating a site can drain away quickly. Maintenance of the drainage system, including ditches and shallow surface drains (known as grips, gutters or foot drains) is therefore essential to the conservation of these meadows.

Key management issues and solutions

The traditional farming system is essential for the conservation of floodplain meadows. Inappropriate grazing or hay-cutting regimes, including abandonment and dereliction, are likely to result in deterioration. Key issues are under-grazing, changes in the timing of hay cuts, eutrophication and alterations to the drainage patterns and water-level management (Figure 9.1).

Decisions about what management action to take at a site can be made by looking for key plant indicators, or by recognition of change in typical management activity. For example, extensive summer floods may result in a missed or late hay cut. If this happens over several years, bulky pond-sedges are likely to proliferate and additional management measures are required to control them, such as the

What a foot drain is and what it isn't

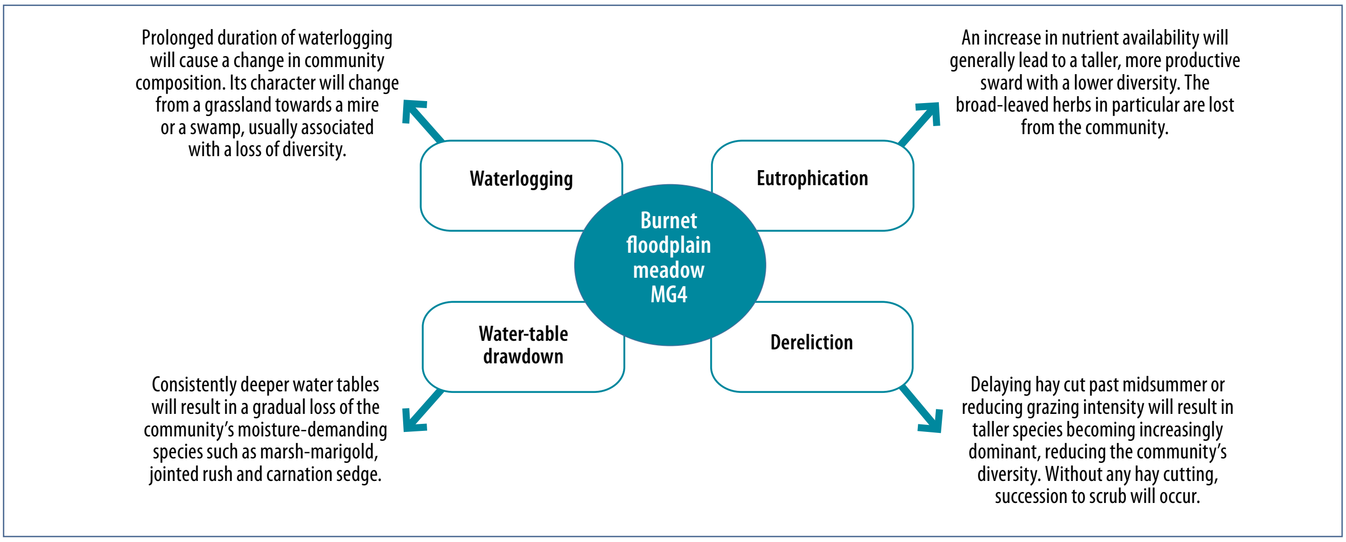
A foot drain is a 30 cm (foot) wide channel no deeper than a garden spade that helps the water on the surface to drain away, enabling oxygen to access the soil. It is not an oversized drainage channel designed to remove all the water in a field leaving no scope for wetness in the soil for plants and animals. Historically, floodplain meadows were often reliant on the management of these small drains. Old maps, LIDAR data and historic aerial photographs may reveal the locations of historic drains that are no longer easily visible on the surface. The maintenance of small grips and foot drains across a site also adds to habitat diversity and can provide feeding areas for birds and invertebrates.

An over-deepened drain that has resulted in the loss of wetland species on the adjacent floodplain meadow.
© Emma Rothero

Creating foot drains using a tractor.
© River Nene Regional Park (RNRP)

Volunteers digging out foot drains.
© (RNRP)

Figure 9.1 summarises the impacts from different management problems using Burnet floodplain meadow (MG4) as an example. Adapted from Wheeler *et al.* (2004) where further examples can be found for different plant communities.



Prolonged duration of waterlogging will cause a change in community composition. Its character will change from a grassland towards a mire or a swamp, usually associated with a loss of diversity.

An increase in nutrient availability will generally lead to a taller, more productive sward with a lower diversity. The broad-leaved herbs in particular are lost from the community.

Consistently deeper water tables will result in a gradual loss of the community's moisture-demanding species such as marsh-marigold, jointed rush and carnation sedge.

Delaying hay cut past midsummer or reducing grazing intensity will result in taller species becoming increasingly dominant, reducing the community's diversity. Without any hay cutting, succession to scrub will occur.

maintenance of ditches (so that floodwaters can be removed more rapidly), and an early hay cut, possibly followed by a second hay cut in autumn.

Flexible management

While ideal floodplain-meadow management sounds simple in principle, in practice it is often not so straightforward, and managers will need to take an adaptive approach. For example, wet conditions may prevent a timely hay cut or even a hay cut at all, or the grazier may unexpectedly be unable to bring livestock onto the site when required. In such situations, it is necessary to be flexible: a late cut may be compensated for by an early cut the following year, or a second hay cut may be taken if grazing is not possible. Variations are likely to have occurred in the past, and may in any case enhance diversity. For example, early cutting favours species such as meadow foxtail, while delayed cutting will benefit later-developing species such as common bent.

The nutrient budget

The eutrophication of rivers (e.g. through waste-water discharge, excessive use of slurry and the erosion of agricultural soils) and increased deposition of nitrogen from atmospheric pollution is increasing the fertility of floodplain meadows (Gowing, Tallowin *et al.* 2002; see also Chapter 6). The accumulation of nutrients alters the balance of plants in the meadow by favouring competitive plants and decreasing the species-richness of the sward. Cutting earlier or twice will help to balance an over-accumulation of nutrients.

Conversely, when a river is embanked, over-deepened or canalised or its flow has been regulated as part of past drainage or flood-management schemes, floodplain meadows can become disconnected from the river. This can result in the meadow no longer receiving a periodic dose of nutrient-rich sediment (Tallowin 1997). Where P levels in the soil decline and the hay crop becomes unviable, or undesirable species appear in the sward such as sharp-flowered rush, the application of FYM may be appropriate.

Plant indicators of environmental problems

Particular plant species can act as useful indicators, showing when the water and soil conditions have changed and are no longer suitable for the desired floodplain-meadow community. For example, sites may become too wet to sustain species-rich meadow communities (see Chapter 8) and this will be seen in the increased presence of species more normally associated with wetter conditions.

Table 9.2 shows particular problem plants, and what environmental or management conditions they may indicate. Management solutions are suggested in each case.

Management for wildlife

A rich array of species have adapted to the cycle of hay cutting, aftermath grazing and periodic inundation. Many of these species benefit from the margins and areas of transition between one vegetation type and another, and management requirements vary. It is important to remember that the historic management at a site will have shaped the range of taxa found there and this pattern should be maintained where known. Adapting management to the needs of a particular species is not advisable as there may be impacts on other interest features.

This section outlines management approaches that can be used for the benefit of different species groups (summarised in Table 9.3). Further information on how to find out what a site is important for is given in Chapter 10. Information about where to find out what sites are designated for is provided in Chapter 4.

Invertebrates

Floodplain meadows provide an important nectar and pollen resource for insects (Potts *et al.* 2010). The cutting of floodplain meadows in itself should not be a problem for characteristic species as they will be adapted to this, but the way in which sites are cut can make a huge difference. The speed of cutting today is much higher than it was historically. Invertebrates have fewer opportunities to escape and can suffer more harm from heavy machinery than they would have under non-mechanised methods (Humbert *et al.* 2010).

Table 9.2 Typical management challenges and the use of plants as indicators of underlying environmental problems. In situations where the named plant becomes frequent across much of the meadow and dominant in some areas, management solutions are presented.

Plant	What does this indicate?	Possible causes	Possible solutions[A]
Soft rush	Waterlogging Acidification Soil disturbance	Silting up ditches and grips Stock poaching in wet conditions	Restore surface drainage Apply lime Avoid overgrazing
Sharp-flowered rush	Wet soil Low nutrient availability	Silting up ditches and grips	Improve surface drainage and consider addition of farmyard manure (FYM)[B] Cut before flood likely, to drown shoots
Greater pond-sedge	Waterlogging Late or missed cuts resulting in a rank sward	Silting up ditches and grips Late (after 15 July) or missed hay cuts, lack of management	Restore surface drainage Cut early (mid June)
Reed sweet-grass, reed canary-grass	Ditch siltation and water overspill into meadow resulting in waterlogging	Silting up ditches and grips	Maintain ditches Cut twice (or at least once!)
Slender tufted-sedge, lesser pond-sedge	Ponding of low-lying areas Consecutive wet summers	Silting up ditches and grips	Maintain surface drains Cut twice annually for three years (see Case Study 9.1)
Common nettle	Eutrophication	Late or missed hay cuts Flooding with nutrient-rich water	Cut early (mid June) Cut twice annually (June and September) Maintain surface drains Work with agencies to reduce nutrient levels in wider catchment
Marsh ragwort[C]	Waterlogging Soil disturbance	Silting up ditches and grips Stock poaching in wet conditions	Repair surface drainage Cut early (mid June) Avoid overgrazing Consider winter sheep grazing
Hogweed	Eutrophication Lowering of water level in the river or ditches	Flooding with nutrient-rich water Late or missed hay cuts Alteration of river management Over abstraction	Maintain surface drains Work with agencies to reduce nutrient levels in wider catchment and assess water levels Cut early (mid June) Cut twice annually (June and September)
Curled dock	Waterlogging Eutrophication	Silting up ditches and grips Late or missed hay cuts	Restore surface drainage Cut early (mid June)
Spear thistle, creeping thistle	Eutrophication Soil disturbance	Late or missed hay cuts Stock poaching in wet conditions	Cut early (mid June)[D] Avoid overgrazing
Creeping buttercup, hard rush	Compaction resulting in waterlogging	Poor timing of grazing and vehicle access	Avoid vehicle access in wet conditions; avoid grazing when soil too wet to support animals
False oat-grass, creeping thistle	Accumulation of ditch spoil above the normal field level	Insensitive ditching works	Spread ditch spoil
Tussocks of coarse grasses (e.g. false oat-grass, cock's-foot, tufted hair-grass, Yorkshire fog)	Late or missed cuts Lack of grazing	Late or missed hay cuts Accumulation of litter through under grazing	Cut early (mid June) Cut twice annually (June and September) Temporary fencing to keep animals in restricted areas Revise stocking densities/reinstate aftermath grazing

A These possible solutions should be considered in the context of the site's conservation objectives. Some solutions may conflict, so action taken will be determined by overriding objectives.
B If FYM is applied then it is best to monitor the vegetation compositions and also sample for extractable phosphorus after a few years. Olsen P should ideally not exceed 15 mg/l^{-1}.
C Marsh ragwort is slightly toxic to stock so can be undesirable in a meadow at high density.
D Herbicide use is not generally recommended if there are other means available as there is a risk of collateral damage.

Table 9.3 Management options in relation to different species groups.

Management options	Species group	Objective
Carry out a breeding-bird survey in spring	Birds	Check if there are any ground-nesting birds using the site and identify locations
Consider a staggered cutting pattern	Birds, invertebrates, mammals	Try to avoid areas where there are nests until young have fledged. If the management history has been disrupted, allow some areas to be cut later than others on an annual rotation to allow small mammals to escape or finish their breeding cycle and to provide invertebrate habitat for longer
Rotate staggered cutting	Birds, invertebrates	When there are breeding birds nesting, avoid nest sites, and avoid cutting the same areas at the same time year on year
OR consider cutting in a spiral pattern from the inside out if corncrake or curlew are present	Birds, invertebrates, mammals	This would enable fledgling birds, invertebrates and small mammals to escape the machinery
Maintain margins and boundaries	Invertebrates	Irregularly cut areas contribute towards an overall habitat diversity in the landscape, which will benefit invertebrates
Leave uncut margins and fringes of vegetation alongside watercourses on a rotational basis	Invertebrates mammals	Allow some margins to be left uncut each year and rotate uncut margins between years
Consider type of livestock	Invertebrates	Beetle abundance was found to be higher in cattle-grazed swards than those grazed by sheep during an aftermath-grazing study (Woodcock *et al.* 2006)

The larvae of the orange-tip butterfly (pictured) and the weevil *Ceutorynchus cochleariae* are both associated with the flower and seeds of cuckooflower and are able to complete their larval life stages before the hay is cut. © Roger Key

The reduced variation in cutting dates between meadows seen today (see *Hay-cutting regime* above) can create a period of landscape-wide food shortage for invertebrates.

General management guidance for invertebrates

Leaving the hay cut for as long as possible in order to benefit invertebrate populations is likely to jeopardise the botanical interest of the site and thus the populations of specialist invertebrates in the long term. Local invertebrate populations will have evolved strategies to cope with management practices. If there is a long history of hay cutting on a site, with a known management pattern, this should be continued to ensure adapted invertebrate life strategies can be maintained.

General good cutting practice for range of taxa

- If possible, plan cutting at a landscape scale, and maintain ditches and cut some meadow areas at different times from the main meadow.
- If feasible, mow from the inside out and towards unmown areas.
- Leave some uncut margins until autumn on a rotational basis to provide refuges post mowing.
- Consider which equipment to use. A study by Humbert *et al.* (2010) suggests that hand-pushed motor bar mowers cause less damage than rotary mowers, particularly on ground-dwelling invertebrates because of the smaller size and weight of the machine (impacts through crushing).
- Most meadows are cut using machinery, therefore minimising the number of passes of machinery should be considered.

Given the rarity of floodplain meadows and the potential adverse impact of changing the management routine, the best option to improve conditions for invertebrates in general is to concentrate on creating additional flower-rich grassland or similar habitat in the surrounding countryside for both generalist flower-visiting species and, where possible, specialist flower feeders.

Birds

Understanding how grassland management, such as timing of cutting and the water regime affects birds is very important as it can influence the number of species that can feed and breed on floodplain meadows. Early cutting can affect the breeding success of ground-nesting birds such

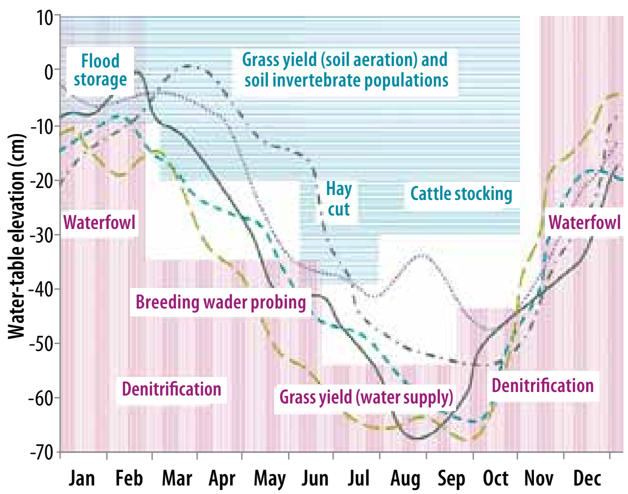
Managing conflicts of interest

There is sometimes a perceived conflict of interest between conserving plant diversity (which usually requires a hay cut in late June and lower spring/summer water levels) and managing for ground-nesting birds and invertebrates (which require a later cut, in early or mid July or later and also, in the case of breeding waders, higher spring/summer water levels). In practice, it should be possible to adopt the relevant management guidelines provided above to ensure plant diversity is maintained while ensuring that populations of ground-nesting birds and pollinating insects are not compromised. For sites managed under an agri-environment scheme, it is useful to talk to Natural England staff about any potential conflicts. For example, some sites (or compartments) may be managed for the maintenance of species-rich grassland, and others for the maintenance of grassland with breeding waders. The recommendations (and payments) are different, so for sites with both it is important to strike an appropriate balance.

Figure 9.2 illustrates how it should be possible to manage water levels for the benefit of all interests, by demonstrating the water needs for different interest groups throughout the year.

The graph shows the range of water-table depths for named interests that should be avoided on a regular basis to prevent deleterious impacts. For example, if the water levels lie between 40 cm and 20 cm below ground during June and July, when the hay should be cut, this may make the soil too wet for machinery to access the site without compacting the soil. If the water levels are lower than 35 cm below ground from mid February to mid June regularly this could be problematic for breeding wader probing. A conflict of interest may arise where water levels may be too dry for waders, and too wet for a hay cut (mid June) but in reality, weather conditions in each year will be different, and will largely dictate overall site management. The dotted lines represent actual water-table positions for a meadow in Somerset for five separate years to illustrate the year-to-year variations caused by varying weather patterns.

Figure 9.2 The importance of inter-annual variation (after Spur *et al.* 1996).



Hay making at North Meadow, Cricklade in 2014. © Mike Dodd

as skylark and curlew by destroying nests before the young have fledged. Delaying hay cutting increases the abundance of seeds and invertebrate prey for birds; however, increasing sward height and density can impede access to food and limit the meadows' attractiveness as a food source. Where the meadows are highly fertile nesting can be impeded.

General management guidelines for birds

If breeding birds are likely to be present it is wise to carry out a survey during the spring and identify what and where they are. Nesting locations can then be avoided when the meadow is mown, leaving areas with nests to be cut later, after the young have fledged. Case Study 9.3 demonstrates where this approach has been taken for Upham Meadow SSSI in Gloucestershire. It is not beneficial to cut late (e.g. mid/late July) every year if there are no breeding birds, as this will be detrimental to plant communities and quality of the hay (Humbert *et al*. 2012).

It is illegal to damage the nest of a breeding bird so where nest sites are known, avoiding action should be taken[36]. More information about managing sites for breeding birds can be found in *The Wet Grassland Guide*[37].

Mammals

The growth of vegetation in the spring offers opportunities for small mammals, but these are short term as the subsequent cutting and grazing makes the habitat largely unsuitable. However, any pockets of tussocky grassland and taller herbs that are managed on a longer rotation within the habitat mosaic can be beneficial for small mammals such as harvest mouse. The banks of rivers and ditches that run through floodplain meadows can provide habitat for otter, water vole and water shrew.

The economic value of a hay crop

The traditional management of floodplain meadows produces a sought-after hay crop that can have an economic value. 2013 prices[38] for pick-up baled hay (approx. 40 bales per tonne) were £80 per tonne (t). Table 9.4 provides costs and profits for a site in south-east England and further examples are discussed below. Case Study 9.4 shows costs and profits for Wheldrake Ings in Yorkshire, in 1910–1911.

Table 9.4 Costs and income generation from a hay crop.

Item	Measure per unit	Total
Size of site	-	30 ha
Cropping rate	5 tonnes/ha	150 t
Small bales	40 per tonne	6,000
Contractor costs	£1 per bale (small)	£6,000
Price of hay	£80 per tonne	£12,000
		Profit £6,000

Kingsthorpe Meadows, Northamptonshire (see Case Study 9.2)

Three fields that were previously sporadically grazed are now in hay production. In 2014, about 30 tonnes were produced from these meadows. The Bedfordshire, Cambridgeshire and Northamptonshire Wildlife Trust (BCN) saved approximately £1,777.50 in 2014, plus they gain a small income (£450 per year) for the horse grazing on the site. Previously there was little economic benefit from the site.

Chimney Meadows, Oxfordshire

In 2013, Berkshire, Buckinghamshire and Oxfordshire Wildlife Trust (BBOWT) sold 120 tonnes of hay in large square bales at approximately £65 per tonne (£7,800 total). They also made some traditional small bales (600–800 per year), some for their own use and some (250) to sell locally. The 250 small bales were sold at £140 per tonne[39] (£875).

A note of caution

It should be noted, in years when the weather has been particularly poor and it is not possible to make hay, or if there is a surplus of high-quality hay around, it may not be possible to recoup the costs of cutting and removing the vegetation. Although such years are relatively rare, it is important to have a contingency plan in place. Removal of cut vegetation is essential for achieving conservation objectives and for maintaining a high quality of hay crop the following year, and so is a high priority even if it is not possible or financially viable to sell the hay. A long-term financial view is required for hay cutting on meadows, as some years will see a profit from a hay crop, while in others there will be the cost of removing the cut vegetation. Hay making on a floodplain is a long-term and sustainable option as the plants can accommodate the varying patterns of flooding and drought, utilising the silts that are deposited effectively and generating an income in most years with no inputs.

Many thanks to additional contributors Stuart Baker, Sarah Blyth, Simone Bullion, Martin Hammond, Louise King, Lisa Lane, Sonia Newman, Toos van Noordwijck, Alan Shepherd, Mike Smart and Alisa Watson.

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[36] http://www.rspb.org.uk/forprofessionals/policy/wildbirdslaw/birdsandlaw/wca/index.aspx
[37] Can be purchased from RSPB. Contact conservation-advice@rspb.org.uk
[38] http://www.farminguk.com/MarketData/HayStrawMonthly/Pickup-Baled-Meadow-Hay-2011-2016-_176.html
[39] At £3.50/bale with approximately 40 bales/tonne

CASE STUDY 9.1
Control of invasive sedges

Invasive sedges, such as slender tufted-sedge and lesser pond-sedge, have been identified as problems on floodplain meadows in the UK and across western Europe as they reduce species diversity and decrease the quality of the hay crop. They are more tolerant of waterlogged soils than many other floodplain-meadow species, and can become established following a series of wet summers.

Newman (2013) looked at the effectiveness of a double-cut treatment in controlling these sedges, together with the effects of this treatment on the wider plant community. Potential mechanisms regulating the spread of these two species were also investigated. Field trials were set up to monitor the effects of the cutting treatment and pot experiments were undertaken to assess the effects of cutting on plant behaviour.

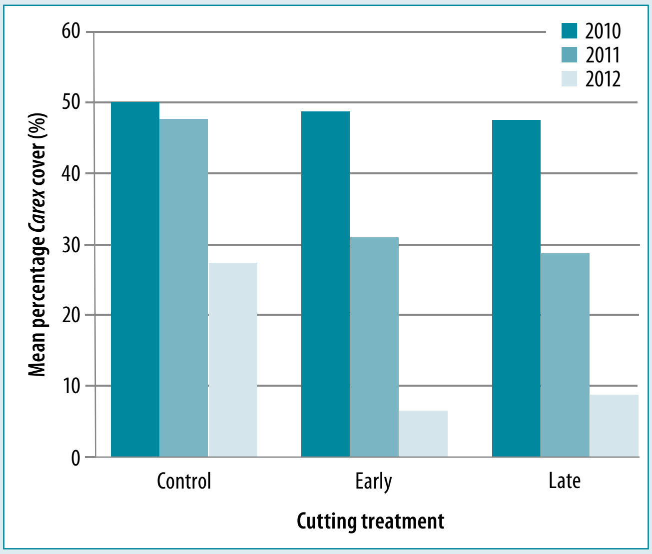
Findings

- A double cut successfully controlled both slender tufted-sedge and lesser pond-sedge on floodplain meadows.
- The frequency of the cutting treatment was more important than the timing of the additional cut.
- Flowering in slender tufted-sedge was significantly decreased by cutting twice.
- The timing of the cuts had no significant effect.

Recommendations for controlling slender tufted-sedge and lesser pond-sedge[40]

- Cut the vegetation in mid June and again at the end of August if field conditions allow.
- Graze during autumn if there is sufficient re-growth.
- Maintain the double-cut regime for three years, which should be sufficient to control sedge invasions, providing excessive waterlogging does not recur.

Figure 9.3 Differences in response of slender tufted-sedge and lesser pond-sedge from varying cutting regimes (Newman 2013). Control equates to a single cut in each year, an early cut equates to cutting in May and again in July and a late cut equates to a cut in June and again in August.



Lesser pond-sedge. © Mike Dodd

Slender tufted-sedge. © Mike Dodd

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[40] These possible solutions should be considered in the context of the conservation objectives for the site. Some solutions may conflict, so action taken will be determined by overriding objectives.

CASE STUDY 9.2
Changes in management at Kingsthorpe Meadow LNR, Northamptonshire

Historically, Kingsthorpe Meadow was lightly grazed by horses and cattle on alternate years. The three southernmost meadows were managed as water meadows until the 1940s. The western meadow on the north side was flooded in winter and allowed to freeze for the villagers to skate on.

The River Nene regularly floods, and the site has several old foot drains. The vegetation in 2009 was species-poor with bulky sedges and had severe problems with ragwort, dock and creeping thistle. The site objective had been to increase its use by birds such as wintering snipe. There is no public access.

Techniques used

A soil survey undertaken in autumn 2010 indicated that the soil had a high clay content, making it susceptible to compaction, but that some deep drainage was occurring as the soil profile showed good aeration at depth. A soil pit dug in spring 2011 confirmed that compaction was not a major problem. An NVC survey in summer 2011 found great burnet, meadowsweet and meadow foxtail in an adjacent compartment, suggesting that hay cuts had been undertaken in the past, and that a suitable hydrological regime might still exist over the site.

Kingsthorpe Meadow (compartment 2) has been managed by Bedfordshire, Cambridgeshire and Northamptonshire Wildlife Trust for Northampton Borough Council since 1993. It is now in an HLS agreement. © RNRP

Based on this information, a decision was taken to change from pasture to meadow management to increase the plant-species diversity and so control the spread of bulky sedges. In addition to hay cutting and aftermath grazing, hand pulling of weeds such as ragwort was carried out in the first year.

Monitoring

An NVC survey undertaken before the change in management provides a baseline against which future surveys can be compared. Fixed-point photography is undertaken.

Results

Fixed-point photography shows the meadow to be improving. Yellow-rattle, ragged-robin, common knapweed, great burnet and fine grasses have spread throughout the site. There are more wintering waders than before, with as many as 12 wintering snipe at any one time, and wintering lapwing, golden plover and curlew have been recorded since the change in management.

The start of hay cutting has resolved issues with weed species. Negative indicators such as bulky sedges and rushes appear to have decreased, whilst common ragwort and dock have been eliminated.

Benefits

- Increased offtake of nutrients from the Nene catchment through cropping for hay.
- Economic benefit through sale of hay and grazing (see ‘The economic value of a hay crop’ on page 64).
- Creation of 1.91 ha of flower-rich pollinator habitat.
- Creation of a demonstration and discussion site.

Kingsthorpe Meadow in 2015. © RNRP

CASE STUDY 9.3
Staggered cutting times to protect curlew nests at Upham Meadow, Gloucestershire

Upham Meadow is a designated SSSI for populations of breeding waders, including curlew, and over-wintering populations of waders and wildfowl. The site also retains significant botanical interest, including one of the largest populations in Britain of the nationally scarce narrow-leaved water-dropwort, in addition to areas supporting relict floodplain-meadow plant communities. It is a traditional Lammas meadow, managed by a commoners' association.

Historically, this Lammas meadow was always cut in narrow strips and it would have taken several weeks before the whole field was completely cut. More recently, an increasing proportion of the meadow was being cut earlier in June. To manage the negative impacts of more uniform and earlier cutting on breeding curlew, the traditional cutting pattern was enshrined in a new HLS agreement (2009), which now requires commoners to cut a significant portion of the meadow later, on a rotational basis (Figure 9.4). Three cutting times are specified: 15 June, end of June and mid July. Each year the cutting times are rotated, so no strip is cut at the same time for two years running. Curlew surveys are carried out to identify nest sites, and cuts are organised to avoid these. Since implementation, curlew numbers have remained stable particularly when compared to the wider Severn Vale.

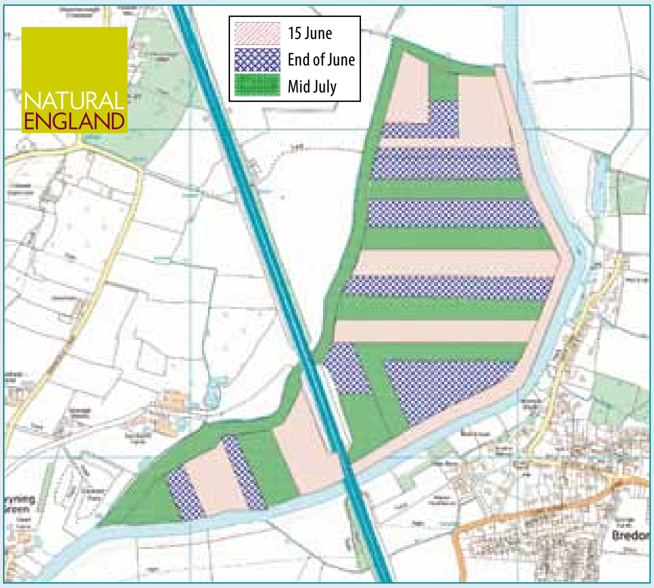


Figure 9.4 In order to deliver HLS agreement and receive payments, the commoners at Upham Meadow must cut their strips in rotation. © Natural England 1000046223 (2006) with drawn outlines courtesy of Alisa Swanson.

CASE STUDY 9.4
Historic management at Wheldrake Ings, Yorkshire

The historic management costs of Wheldrake Ings are shown in Tables 9.4 and 9.5. Activities required to maintain a functional floodplain meadow included drain digging, fence mending and mole catching amongst others. The document lists "looking after clue" (i.e. looking after ditches) and "Clough Dyke dressing out" (clearing out ditches), as well as the provision of bread, cheese and beer for banking men! The management of an Ings in 1911 (from Warburton 2006) was a serious undertaking, costing the equivalent of £3,000[41] in today's money to carry out the tasks described below.

Table 9.4 An extract from the accounts of Wheldrake Ings in Yorkshire in 1911 (from Warburton 2006) showing trends in rates, income and wages. Case Study 10.4 (Chapter 10) demonstrates current-day drainage management at Wheldrake Ings.

	1874–75	1880–81	1887–88	1888–89	1910–11
Rate levied per acre	3s-10d	2s-0d	2s-6d		1s-6d
Total income on 275 acres	£52-14s-2d	£27-20s-0d	£34-0-0d		£20-12-6d
Wage per day for 1 man	3s-0d		2s-9d	2s-8d	

Table 9.5 (right). The disbursement of Wm. Hick, J.B. Hall, W.J. Smith, J. Buckton being Bylaw men from 16 November 1910 to 15 November 1911 showing costs associated with different elements of management (from Warburton 2006).

	£	s	d
Taking banking things & back from Ings		6	0
Taking workmans things & back from Ings		6	0
Mole catching		9	0
Beer for banking men		2	0
Mr Wright for use of boat		11	0
R. Biscombe 2 days leading gravel to bridge		14	0
Taking woodwork to clue		3	0
Taking 1 ton of cement to bridge		3	0
" part of a ton		2	0
J. Bielby for mowing old dyke out		7	0
Breaking day	1	0	0
Ings masters	2	0	0
Looking after clue		10	0
Collecting rate		10	0
J. Myers bill		12	6
Pacey for Low Marr ditch 25 chains at 3/6 (22 x 25 = 550 yds)	4	7	0
Fencing and wood	1	0	0
Cheese and bread		5	0
Notices and postage		3	0
W. Barker for looking after ditches	10	0	0
Pacey for 35 chains (700 yds) low Ings dyke at 2/0	3	10	0
Ditto 11 chains from Ploug? Hole at 1/0		11	0
Ditto Clough Dyke dressing out		8	0
Garbutt new rope 10 yds		8	6
2 men and 1 cart ½ day in Ings		5	0
	28	**13**	**6**
Recvd by rate at 1/6 per acre		12	6
Balance from last year	6	8	4
	27	0	10
Balance due to Ings masters	**1**	**12**	**6**

[41] http://www.thisismoney.co.uk/money/bills/article-1633409/Historic-inflation-calculator-value-money-changed-1900.html

Chapter 10
Restoration and creation of floodplain meadows

Clare Lawson and Emma Rothero

This chapter summarises the importance of restoration and creation. It outlines the steps involved in deciding what action needs to be taken based on a site assessment. It considers the different practical methods for restoration and creation, also considering the needs of the landowner. Examples are provided through real-life case studies.

Why carry out restoration and creation of floodplain meadows?

Floodplain meadows are highly valued for their wildlife, landscape and history. They support many uncommon species including the iconic snakeshead fritillary and increasingly scarce breeding waders. However, since 1940, they have mostly been converted to intensive grassland and arable cultivation, so only a scatter of small vulnerable sites remain. Their value to society in terms of floodwater and nutrient storage are increasingly being recognised, and they offer a sustainable and cost-effective means for producing an agricultural crop on floodplains.

As well as protecting surviving floodplain meadows, we need to restore as many as possible and create new ones. In addition to increasing the total area of species-rich grassland, these actions will create protective buffers around existing areas and link fragmented sites, increasing the benefits they provide to society, and enhancing the resilience of their rare plant communities to external pressures such as climate change (e.g. increased frequency and intensity of floods and droughts). As well as restoring floodplain meadows for their own sake, it is worth restoring and creating floodplain meadows for the following reasons:

- They are a productive system adapted to a floodplain environment needing minimal inputs, remaining productive even during droughts.
- They can form part of viable commercial enterprises, producing good quality, sustainably produced hay and nutritionally valuable forage for livestock grazing in late summer and early autumn.
- They support a range of wildlife that has now almost vanished from Britain including pollinating insects and rare species.
- They represent an important element of our rural history and are part of our cultural heritage that we should protect.
- They are an integral part of cherished rural landscapes as painted by Turner and Constable and celebrated by poets and writers.
- They provide storage of carbon, sediments, nutrients and floodwaters.
- A change from species-poor pasture or arable to species-rich meadow will result in a net reduction of nutrients in the catchment through hay cropping and a reduction of artificial inputs (fertilisers, pesticides).
- They provide an important resource for education and research, personal enjoyment, rest, relaxation, mental and physical health and well-being.

Floodplain meadows can provide places for learning, bring communities together and inspire collective action.
Left: Sherborne Meadow, Warwickshire. © Emma Rothero **Right: North Meadow, Wiltshire.** © Mike Dodd

Definitions for restoration

Creation – the establishment of a meadow on an area which has lost all characteristics of a meadow, for example on arable land or on improved grassland that has been re-seeded with agricultural plant varieties.

Restoration – the restoration of a floodplain meadow on an area of grassland which has undergone substantial changes in management (e.g. more intensive farming or changes in water level), but that still retains some of the characteristics of the original habitat, such as a permanent grassland that has not been re-seeded and has retained functioning floodplain-meadow hydrology.

Target community – the botanical goal of the restoration/creation project.

Assessing the potential for floodplain-meadow restoration or creation

Subtle changes in hydrology, topography and soil fertility can result in large shifts in floodplain-meadow plant communities (Gowing, Tallowin *et al.* 2002). The soil-water regime and topography determine where different plant communities will grow. Soil fertility is also key; for example, the amount of available phosphorus in the soils of a Burnet floodplain meadow (MG4), is typically between 5 and 15 mg l^{-1} (Gowing, Tallowin *et al.* 2002). So, before exploring the options further, it is essential to collect information about soil type, structure and fertility, hydrology and topography through a **site assessment**, as this may reveal issues that will need to be addressed before restoration or creation can take place.

As a minimum, a site assessment should examine the factors listed in Table 10.1. Approaches are outlined below and further information given in the chapters indicated in Table 10.1. Past and current management should also be taken into consideration.

There may be plants on site that also indicate soil-water and soil-fertility conditions. Table 10.2 lists species indicative of particular plant communities, and therefore particular soil-water and soil-fertility levels.

If the assessment indicates that the various factors are within the ranges that will support species-rich floodplain meadow, follow the chart in Figure 10.1. If the assessment reveals that some elements are not within range, follow the chart in Figure 10.2.

Table 10.1 Factors requiring assessment before undertaking restoration or creation. Further information on investigation and monitoring is given in Chapter 11.

	Ideal range for restoration/creation	**Further information within handbook**
Soil fertility	5–25 mg/l^{-1} P	Chapter 6
Soil pH	pH > 5.5	Chapter 6
Soil-water levels	Roughly matching those described in Figure 7.6 for MG4 or MG8 type community^{A}	Chapter 7 Chapter 11
Soil texture and structure	Good soil structure (not compacted), soil profile indicates fluctuating water levels in appropriate zone	Chapter 5

A Soil-water levels given in Figure 7.6 are general ranges for a typical MG4 community. The exact water-level requirements will depend on specific site conditions such as soil type and structure. A simple Excel spreadsheet is available (see page 93 in Chapter 11) which will predict plant community based on soil-water and soil-type data.

Figure 10.1 How to determine the best approach at a site where soil fertility, water levels and soil structure are within the range expected for a species-rich floodplain meadow, but the botanical community is species-poor. Case studies are listed at the end of this chapter.

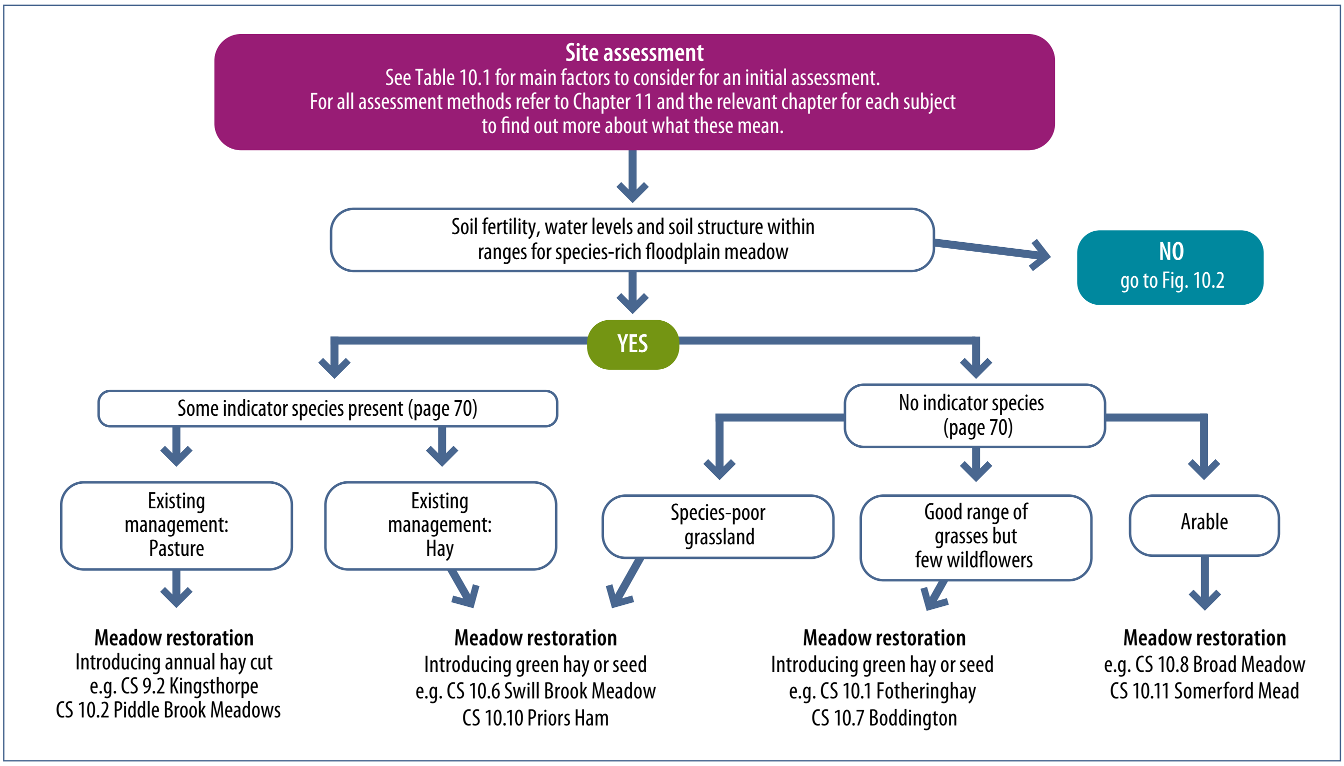
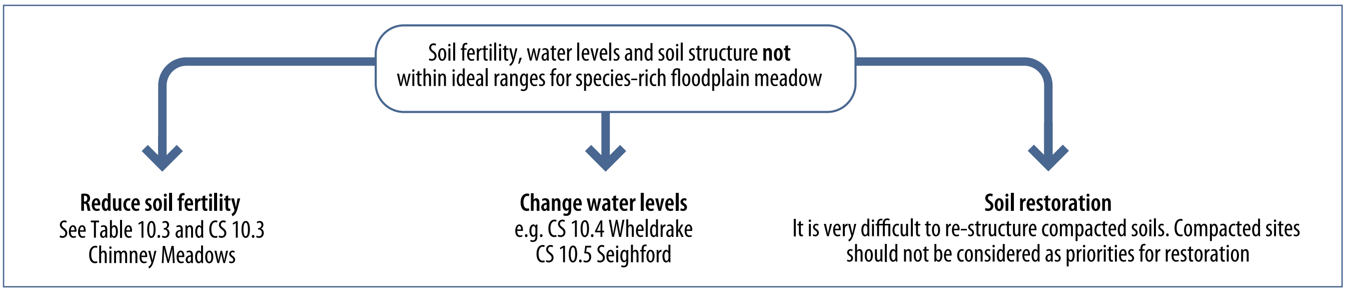


Figure 10.2 How to determine the best approach at a site where soil fertility, water levels or soil structure are not within the range expected for a species-rich floodplain meadow. See the relevant section below for specific information on when restoration or creation of floodplain-meadow communities may not be the best option for a site.



Plants

If the site supports plant species of interest (i.e. vegetation other than arable crops or leys of perennial rye-grass and white clover), they will be useful indicators of the existing soil and water conditions. For example, plants such as oxeye daisy and quaking-grass are adapted to drier conditions whilst others, such as pepper-saxifrage and meadow foxtail, can tolerate short periods of flooding. If the site has tall vegetation dominated by vigorous plants such as common couch, hogweed or curled dock, this indicates a highly fertile soil which will not develop floodplain-meadow communities until the soil fertility is reduced. A first step is therefore to carry out a baseline survey (see Chapter 11) to collect information on the plant species present and their relative abundance.

Table 10.2 lists plants that indicate that soil and water conditions may be appropriate for the restoration of characteristic floodplain-meadow plant communities. The presence of even one or two of these species suggests that the site has potential. For example, Burnet floodplain meadow (MG4) is tolerant of short periods of flooding and is found on **well-drained alluvial soils**. If the site has several of the characteristic species, the soil and water are likely to be appropriate for the restoration of Burnet floodplain meadow (MG4).

If the site supports plants more tolerant of **dry conditions**, the restoration of Knapweed meadow (MG5) would be a more suitable objective. Sites with a constantly moist soil may be suitable to restore Kingcup-carnation sedge meadow (MG8). However, if the site supports plants more tolerant of **prolonged water logging** (Table 10.2, column 4), drainage issues will need to be addressed before attempting conversion to floodplain-meadow communities. Some plant species, such as common knapweed, are found in more than one meadow community. In most cases it will be necessary to supplement the botanical survey with direct measurements of soil and water conditions.

Table 10.2 Plants that indicate that soil and water conditions are appropriate to restore floodplain-meadow plant communities (see Chapter 8 for community descriptions) or that indicate prolonged waterlogging. Adapted from Gowing, Lawson *et al*. 2002.

Knapweed meadow (MG5) (dry conditions)	**Burnet floodplain meadow (MG4)** (well-drained alluvial soils)	**Kingcup-carnation sedge meadow (MG8)** (constantly moist soil)	**Species indicative of prolonged waterlogging**
Hemp agrimony	Great burnet	Marsh-marigold	Creeping bent
Downy oatgrass	Meadow foxtail	Brown sedge	Marsh foxtail
Bulbous buttercup	Common knapweed	Common sedge	Slender tufted-sedge
Field scabious	Red fescue	Creeping-jenny	Common spike-rush
Salad burnet	Meadowsweet	Common marsh-bedstraw	Reed sweet-grass
Green-winged orchid	Lady's bedstraw	Ragged-robin	Floating sweet-grass
Rough hawkbit	Meadow vetchling	Tufted forget-me-not	Tubular water-dropwort
Burnet saxifrage	Autumn hawkbit	Marsh ragwort	Amphibious bistort
Smooth hawk's beard	Cuckooflower	Marsh stitchwort	Curled dock
Common knapweed	Pepper-saxifrage	Common meadow-rue	


Field scabious.


Great burnet.


Ragged-robin.


Amphibious bistort.

Photos © Mike Dodd

Plants also give big clues about management history. A site that has a good range of grass species but no or very few herbs, is likely to have been treated with herbicide in the past and may therefore still retain appropriate soil-water and soil-fertility conditions and be very suitable for restoration. Case Study 10.1 demonstrates this situation and is now subject to seed spreading to increase the diversity of herbs in the sward.

Soil fertility and pH

It is vital to carry out an assessment of soil fertility before attempting to restore or create a species-rich floodplain meadow, as this will determine whether or not it is feasible. Floodplain meadows require soils that have moderate levels of soil nutrients, particularly phosphorus (P) (Critchley *et al.* 2002). Soils should be analysed for extractable phosphorus, potassium and magnesium. Levels of these major plant nutrients will give a good indication of whether the site is suitable for floodplain-meadow restoration or creation. In particular, if soil phosphorus is too high, it needs to be reduced before seeding is attempted, typically through more intensive vegetation management for a number of years. Table 10.3 outlines some methods for reducing high levels of P.

Soil pH should also be measured, as sites that are too acidic (pH < 5.5) are also unsuitable.

Soil texture and structure

Soil texture and structure influence water retention and drainage and so information about the soil is needed before restoration/creation is attempted at a site. If the soil is compacted, waterlogging will reduce the availability of oxygen for plants (see Chapter 5), making the site unsuitable for species-rich floodplain-meadow vegetation. The presence of extensive creeping buttercup or hard rush at a site suggests compaction. A site with severely compacted soil is probably not one to target for meadow restoration. A soil pit showing soil structured as horizontal plates with few or no vertical fissures would indicate this.

Table 10.3 The suitability of soils with different extractable phosphorus levels for floodplain-meadow creation or restoration.

Index[A]	Olsen's P Range (mg/l^{-1})	Comments
0	0–9	5–15 mg/l^{-1} P is the range within which many species-rich floodplain-meadow sites are found
1	10–15	This range should be perfect for the typical floodplain-meadow plant community
2	16–25	Species-richness declines above 20 mg/kg^{-1}, but it is still worth attempting restoration/creation within this range
3	26–45	Consider reducing P levels by growing a catch crop such as barley on arable, or reduce P on improved grassland through hay crops (up to two per year). It might take several years before P levels start to fall, particularly on clay-rich soils
4	46–70	Values above 50 mg/l^{-1} are probably too high for restoration unless drastic measures such as topsoil stripping or soil inversion, deep ploughing or chemical amendment can be undertaken

A The P index for a soil reflects the amount of P present ranging from index 0 (very low fertility) to index 9 (very high fertility). More information about these can be found in Natural England Technical Information Note TIN036 'Soils and agri-environment schemes: interpretation of soil analyses'. http://webarchive.nationalarchives.gov.uk/20151201000001/http:/publications.naturalengland.org.uk/publication/23030

Marsh-marigold grows where the soil is constantly moist.
© Mike Dodd

Water

Water management is key to the restoration and creation of floodplain-meadow plant communities, which require particular hydrological conditions (see Chapter 7). The proximity to the water table and its seasonal variation is very important as it determines the length of time that the soil is 'dry' or 'wet', which in turn influences the plant community. For example, the Burnet floodplain meadow (MG4) community is typically found at sites with 10–20 weeks of wet soil and 10–20 weeks of dry soil (see FSC 2010 and Chapter 7 for more details). Installing dipwells (Chapter 11) will give more information and enable monitoring of water levels throughout the year.

Objectives and targets

Once the soil and water conditions have been determined, it is possible to develop general objectives for the restoration or creation project. Plant communities take time to develop and will vary according to soil type, water levels, soil fertility, geographic location and past management, amongst other factors. NVC communities can be used for guidance, but should not be used too prescriptively. It is better to focus on using appropriate restoration techniques, management and monitoring to achieve the most species-rich vegetation possible.

Practical methods for restoration and creation

There are a number of different methods for increasing the species diversity of a site. The approach chosen will depend on the results of the site assessment. To change the characteristics of the site prior to sward enhancement, a change in management, reducing fertility, managing water levels or treatment of compacted soils may be required.

Introducing a change in agricultural management

At some sites, the generally favourable soil characteristics and water regime, together with the presence of a number of key plant species, may mean that a simple change in management is sufficient for restoration. For example, a change from management as pasture to hay cutting is being trialled on a number of sites in the UK (see Case Study 10.2: Piddle Brook Meadows in this chapter and Case Study 9.2: Kingsthorpe Meadows in Chapter 9). More intensive agricultural management may also be introduced on a temporary basis (see below).

Reducing excessive fertility in the soil

The most suitable sites for restoration are those where the soil fertility is moderate. However, the use of artificial fertilisers, particularly nitrogen and phosphorus (which is relatively persistent in soils), have increased the fertility of many farmland soils. On more fertile sites, nutrient levels will need to be reduced before species-rich swards will develop. There are several techniques that can be used (Walker *et al*. 2004). For arable soils, fertility can be reduced by taking arable crops for at least one or two years without using any fertiliser. For improved grasslands, the same is possible through cropping for silage or hay. Case Study 10.3: Chimney Meadows demonstrates reduction of soil fertility through an annual hay cut over ten years. More intensive methods could be considered, such as removal of topsoil and turf stripping, but these are more costly and run the risk of damaging soil structure.

Changing the soil-water regime

While it is essential to introduce seed to sites where floodplain-meadow communities have been lost, for meadows where characteristic plants still survive, restoration may only require changes to the water management.

Water-control structures, usually found in ditches, can be manipulated to manage water levels, but many floodplain meadows do not have such infrastructure. In many cases the maintenance or reinstatement of small foot drains, gutters or grips in the soil is required to ensure water can drain away effectively during the spring and summer, creating aerobic conditions for plant growth.

It is important to keep culverts and other drainage routes clear from potential blockages, so that water does not pool behind them, resulting in a change in the plant community (see Case Study 10.4: Wheldrake Ings and Case Study 10.5: Seighford, Staffordshire).

Drains and ditches can also be used in cases where a site has become too dry. The water table can be raised by bringing water onto a site from an area of high water such as a river or lake and feeding it through a series of carefully spaced channels. A thorough understanding of water movement, soil types and water quality is needed. Such activities may also require an abstraction licence, adding time and expense to the operation. If complicated water-control mechanisms are required to create suitable conditions, floodplain-meadow restoration or creation may not be the best option at a site.

Managing compacted soil

It is possible to improve compacted soil as soil will over time improve its structure, but it can take some years. Compacted soil is poorly draining, has a lack of aeration and will stay waterlogged for prolonged periods. To produce a diverse meadow community on such a site, the key thing to address is the soil structure. Management options are (see Table 10.4):

- improved drainage e.g. digging shallow grips to let any ponded water flow off the site in early spring;
- improving the structure directly by using a sub-soiler (but water must be able to drain from the site, so drainage infrastructure should be improved first);
- adding organic matter to the soil to speed up its restructuring – spreading old farmyard manure (several years old so that most of the nitrogen has gone) could be considered; and
- maintaining an annual hay cut which will gradually deplete the nutrient pool, taking some of the vigour out of species such as creeping buttercup and giving other species a chance. Cutting in late June rather than July would give best results.

Be very careful with stocking on such a fragile soil, i.e. take stock off as soon as their hooves start sinking in and leaving marks. Grazing in spring may not be a sensible option unless the weather is very dry. Grazing in wet conditions will slow down the speed of soil recovery.

Re-introducing plant species

Sward disturbance

Once the site characteristics are appropriate, sward disturbance and enhancement may be required. Where the goal is to diversify an existing grassland, disturbing the existing sward is essential to enable introduced seeds to germinate (Foster 2001). Power-harrowing the grassland before introducing seed is very effective at promoting germination (Hofmann and Isselstein 2004) and increasing plant diversity (Edwards *et al.* 2007). However, care is needed as soil disturbance can also promote the establishment of unwanted species such as soft rush (this species also indicates that the drainage regime needs addressing, as soft rush benefits from waterlogged soil).

Table 10.4 Activities that can be undertaken to improve compacted soil structure.

Action	Management options	Reason
Resolve drainage issues	Clean out ditches, install grips or foot drains	Ensures water can leave site effectively
Maintain annual hay cut	Cut in June if possible	Reduces vigour of infesting species such as creeping buttercup, depletes nutrient pool
Protect and improve soil structure	Manage stock carefully and wait	Prevents further damage to fragile soil
	Add organic matter Consider using a sub-soiler	Improves soil structure more rapidly if funds and time allow

A network of shallow cross drains created to facilitate removal of water from the top layers of the soil to preventing soil waterlogging and anoxia. © RNRP

There are a number of ways to re-introduce appropriate plant species to sites where they are no longer present. These include relying on the seed bank or natural dispersal of propagules, spreading dry or green hay, sowing brush-harvested seed from a nearby meadow, or sowing a commercial seed mix. While such approaches can be successful, it should be remembered that there is always a chance that drought or flooding might limit establishment in any given year, and cannot be controlled.

Using existing seed bank or seed rain as a source for meadow creation and restoration

When creating or restoring a floodplain meadow in situations where there are few or no characteristic plants present, consideration should be given as to whether the desired plants could arrive naturally, either from the existing seed bank or through seed rain (seed drop from existing plants in the vicinity). The evidence suggests that most floodplain-meadow plants have transient or short-lived (less than five years) seed banks (McDonald 1993; McDonald *et al.* 1996). Seed from floodplain-meadow plants tends to be dispersed very locally, within 1.5 m of the parent plant, with little being dispersed more than 3 m (Bischoff 2002). Where there are clusters of existing floodplain-meadows upstream from a creation site, seeds may disperse to the new site in floodwater. However, given the scarcity and fragmentation of the habitat, it is likely to be necessary to introduce seed to a meadow creation site.

Introducing seed from elsewhere

An effective means of seed transferral is through spreading dry hay, an approach traditionally used by farmers to repair bare patches. It can be achieved simply by feeding species-rich hay to animals in a field during autumn, and is a very low-cost option. Alternatively, green hay can be collected from a nearby species-rich floodplain meadow and spread immediately (see Case Study 10.6: Swill Brook Meadow, Clattinger Farm), or the seed can be collected using a brush-harvesting machine and dried for later use (see box 'Green hay and brush-harvested seed' and Case Study 10.7: Boddington, Northamptonshire). Where it is not possible to

Green hay and brush-harvested seed

The use of both harvested seed and green hay from local donor sites with appropriate plant communities have been found to be very effective methods for re-introducing species (Edwards *et al.* 2007).

The green-hay method involves the transfer of cut vegetation from a species-rich donor site. It is important that this is cut and then spread on the recipient restoration site on the same day. Standard farm machinery such as silage-making equipment and muck-spreaders can be used.

Collecting the seed from donor sites using a brush harvester requires specialised equipment and requires the seed to be cleaned and stored, which the green-hay method does not. Brush harvesting also fails to collect seed growing on low-growing species (Edwards *et al.* 2007). However, brush harvesting provides an effective method of introducing local seed to sites where green hay cannot be used, as the seed can be stored and kept until required, whereas green hay must be spread immediately. If there is no local site to source green hay from, or no suitable equipment to collect and spread green hay, then brush-harvested seed is a good alternative.

Sourcing and spreading green hay and seed

Sources of information about possible donor sites for green hay include:

- The meadow map on http://www.floodplainmeadows.org.uk/about-meadows/meadow-map
- Natural England's Nature on the Map www.natureonthemap.naturalengland.org.uk/MagicMap.aspx
- The list of Coronation Meadows http://coronationmeadows.org.uk/

Green hay collected from 1 ha of meadow should be sufficient to spread on 3 ha of receiving land, although a ratio of 1 ha spread on 1 ha may give better results (Edwards *et al.* 2007). It must be cut and spread in the same day; if left for longer, the cut vegetation heats up and the viability of the seed is reduced.

If a commercial seed mix is used, the make-up of the mix should be discussed with the supplier, taking into consideration the relative wetness of the site – species tolerant of longer periods of flooding should be included for wetter sites and plants tolerant of longer dry periods on drier sites. Yellow-rattle is a useful species to include, as it is a hemiparasite, gaining some of its nutrients from grasses and suppressing their growth. This can prevent other species from being out-competed by vigorous grasses.

Introducing a large number of characteristic plant species is more likely to result in an appropriate plant community (Manchester *et al.* 1999) and can be an insurance against failure (Yachi and Loreau 1999). For example, if the current water regime is not fully understood or there is some variation across the site, including a range of species tolerant of different water regimes in the mix means that those most suited to the conditions across the site will become established. Plant traits such as life form, seed biology and phenology determine which species will successfully establish (Pywell *et al.* 2003).

The amount of seed sown should be 15–20 kg of seed per ha with 10% of the seed being wildflowers and the rest grasses.

The donor site should be cut at its usual time, when the seed is ready. Of course the timing of the cut will determine which species are successful in the receptor site (Edwards *et al.* 2007).

Seed provenance – does it matter where the seed comes from?

The extent to which floodplain-meadow plants have developed local variants of species is not yet clear – floodplain-meadow plant communities were formerly widely distributed throughout England and the movement of hay from one area to another was common. A study of the genetics of the meadow buttercup found genotypes to be surprisingly uniform throughout the country, suggesting common species such as this show little local specialisation (Oaten 2005). However, consideration should be given to using seeds that are local genotypes and adapted to local environmental conditions (van der Mijnsbruggea *et al.* 2010). Restoration using some commercially available wildflower seed mixtures could introduce other variants which may hybridise or out-compete local variants, although the better commercial seed suppliers collect seed from known sources. As a precautionary measure, seeds should therefore be collected as locally as possible, or at least their provenance should be known.

use dry hay, green hay or brush-harvested seed, commercial seed mixtures can be sown. These are relatively expensive, but have been used successfully for restoring species-rich floodplain meadows (see Case Study 10.8: Broad Meadow, Northamptonshire and box 'Sourcing and spreading green hay and seed').

Managing unwanted species

The seed bank in arable fields is likely to be dominated by annual and ruderal plants and disturbing the soil in preparation for sowing seed will encourage these plants to germinate. Weed control carried out by allowing weed species to germinate and then spraying them with herbicide before sowing meadow seeds on arable sites can improve establishment, although this should only be a temporary problem that will rapidly diminish once cutting and grazing is established and the sward 'closes'. Herbicides must be used with caution and in appropriate weather conditions, especially near watercourses. An alternative is to repeatedly till the soil, leaving sufficient time in between tilling to allow germination of weed seeds. This will exhaust the seed bank and create a stale seed bed.

In some cases, aggressive weeds (e.g. docks, thistles and nettles) or invasive aliens (e.g. Himalayan balsam) may become established. See Chapter 9 for guidance on how to control these species.

Understanding the needs of the landowner/tenant

A floodplain meadow can be a valued part of the farming system. To ensure that this is the case, it is vital that restoration, creation or management takes into account the requirements of the farmer/landowner. Landowners and tenant farmers need to be clear what will be required of them and how long it will take to restore a site – significant changes may occur each year for the first ten years, and possibly take many more years to develop fully. The land manager must be willing to adopt an appropriate management regime, which may include finding a grazier, or altering their own grazing and cutting regime. Introducing grazing for the first time on a farm with no livestock may be the biggest hurdle. This can often be facilitated through agri-environment schemes, which may offer grants to pay for new infrastructure such as fencing, ditching and access to water for grazing animals.

Newly restored or created floodplain meadows are often very productive, resulting in large crops of hay and valuable aftermath grazing while requiring little or no inputs. Farms that have experienced repeated flooding or low productivity may be particularly interested in floodplain-meadow restoration or creation. Case Study 10.9: Oundle Lodge, Northamptonshire, describes floodplain-meadow creation from the landowner's perspective.

How long does restoration take?

Floodplain-meadow restoration can be a long-term process. The speed of success will partly be determined by the prevailing weather conditions. The site may not look very promising even after two or three years if the weather has not been ideal (i.e. floods and droughts), but it is usually worth persisting; for example Case Study 10.10: Priors Ham, Wiltshire, demonstrates the impacts of severe flooding on a restoration site. Some species are only detected several years after being introduced as seed. Somerford Mead, a restoration site in Oxfordshire, see Case Study 10.11, was only considered to be fully referable to the Burnet floodplain meadow (MG4) community after 23 years of consistent management (McDonald 2011).

Funding

Restoring or creating floodplain meadows is not necessarily expensive, although it may be so if the site has to be seeded or there are weed problems during establishment. It is important to have sufficient funding in place, or a clear plan for fundraising, before starting a project. Funding will need to cover project planning, the cost of the work itself, the ongoing costs of managing the meadow, and monitoring change during establishment.

The restoration and creation of floodplain meadows can be funded by grants provided through the Rural Development Programme, such as agri-environment schemes. Information is available from national agencies such as Natural England, whose staff will be able to provide advice on eligibility to enter the scheme. Alternative sources of funding include landfill tax grants, industrial sponsorship, support from grant-making charitable trusts and the Heritage Lottery Fund.

The level of payments from Countryside Stewardship could be £267–£446 per hectare per year for five years for floodplain-meadow re-creation, and £145–£295 per hectare per year for five years for restoration. Payments are also available for capital works such as fencing, gates and drinkers and are paid at approximately 50% of the full cost. The cost of native seed for re-creation is paid at 100% of cost.

Other sources of help

The **Floodplain Meadows Partnership** can offer general advice and site visits. Visit www.floodplainmeadows.org.uk

Statutory bodies such as **Natural England**, **Natural Resources Wales** and **Scottish Natural Heritage** may be able to offer guidance and advice on restoring and creating floodplain meadows, especially if they are providing funds to support the work. Visit https://www.gov.uk/government/organisations/natural-england; http://www.snh.gov.uk/; Natural Resources Wales https://naturalresources.wales/splash?orig=/

The local **Wildlife Trust** may be able to offer guidance from experienced conservationists, and advice on sources of funding. Visit http://www.wildlifetrusts.org/

The **RSPB** may be able to offer on-site guidance and advice for habitat management, both for wintering and breeding waders. They may also be able to offer breeding bird surveys in some areas and can offer advice on breeding wader survey methodologies and potential funding sources for habitat management.

The **Environment Agency** local staff should be contacted at the earliest possible stage when planning such a project, as they can help with information on flooding and water quality, and the need for flood-risk assessments, waste disposal, abstraction and other licences and permits.

View across Fotheringhay Meadow to the River Nene and the historic landmarks of Fotheringhay church and castle mound. © RNRP

Natural England (NE) has produced a series of informative Technical Information Notes (TINs) some of which address issues relevant to the creation and restoration of floodplain meadows. Relevant TINs are listed here, and are available on request from NE.

- **TIN035** *Soil sampling for habitat recreation and restoration* – http://publications.naturalengland.org.uk/publication/31015
- **TIN036** *Soil and agri-environment schemes: interpretation of soil analysis* – http://webarchive.nationalarchives.gov.uk/20151201000001/http://publications.naturalengland.org.uk/publication/23030
- **TIN037** *Soil texture* – http://publications.naturalengland.org.uk/publication/32016
- **TIN038** *Seed sources for grassland restoration and re-creation in Environmental Stewardship* – http://webarchive.nationalarchives.gov.uk/20150909000001/http://publications.naturalengland.org.uk/publication/31014
- **TIN060** *The use of yellow-rattle to facilitate grassland diversification* – http://webarchive.nationalarchives.gov.uk/20151201000001/http://publications.naturalengland.org.uk/publication/23026
- **TIN061** *Sward enhancement: selection of suitable sites* – http://webarchive.nationalarchives.gov.uk/20151201000001/http://publications.naturalengland.org.uk/publication/35008
- **TIN062** *Sward enhancement: choice of methods* – http://webarchive.nationalarchives.gov.uk/20151201000001/http://publications.naturalengland.org.uk/publication/34012
- **TIN063** *Sward enhancement: diversifying grassland by spreading species-rich green* – http://webarchive.nationalarchives.gov.uk/20151201000001/http://publications.naturalengland.org.uk/publication/23025
- **TIN064** *Sward enhancement: diversifying grassland by oversowing and slot seeding* – http://webarchive.nationalarchives.gov.uk/20151201000001/http://publications.naturalengland.org.uk/publication/34011
- **TIN065** *Sward enhancement: diversifying grassland using pot-grown wildflowers or seedling plugs* – http://webarchive.nationalarchives.gov.uk/20151201000001/http://publications.naturalengland.org.uk/publication/32013
- **TIN067** *Arable reversion to species-rich grassland: establishing a sown sward* – http://webarchive.nationalarchives.gov.uk/20151201000001/http://publications.naturalengland.org.uk/publication/35007
- **TIN068** *Arable reversion to species-rich grassland: early management of the new sward* – http://webarchive.nationalarchives.gov.uk/20151201000001/http://publications.naturalengland.org.uk/publication/33012

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CASE STUDY 10.1
Fotheringhay Meadow, Northamptonshire – restoration of a site with good soil structure and water regime

About the site

Fotheringhay Meadow is a privately owned, undesignated 12 ha meadow on the River Nene floodplain. It is managed by the farmer with support from the Nene Valley Nature Improvement Area (NIA).

Historically, the meadow was used for spring sheep grazing until May or June, followed by a hay cut in late July or early August. A walk-over survey showed it to be rich in grasses but poor in broadleaved herbs, although there were small areas with some key herbs including great burnet. This suggested that the site had not been fertilised, but that selective herbicides may have been applied in the past. The NIA wished to explore the restoration potential of the meadow.

Soil survey

A soil profile survey was undertaken at nine sample points using a 1.2 m long auger. For each profile, the depth of the darker surface horizon and the depth to sand and/or gravel were measured, and any mottling of grey/brown (which indicates a fluctuating water table) was noted. The basic profile of the soil across the field was found to be a layer of dark brown loamy clay to about 0.2 m, followed by a band of clay up to 1 m thick. In some places the band of clay was thinner, and had sand and some gravel sitting below it (see Figure 10.3). Cores with sand and gravel within 1 m of the surface showed very little mottling in the clay layer, suggesting that the area the cores were taken from were free draining and had a water regime that could support a more species-rich floodplain meadow. At points where no sand or gravel was found, the clay was dense and had significant mottling (grey/brown), suggesting long periods of waterlogging or poor drainage. The soil cores with sand and gravel were found in areas of higher species diversity.

The low nutrient levels, presence of gravels, low weed cover and low cover of competitive grasses such as cock's-foot and false oat-grass (which can swamp species such as great burnet) all suggested that the chances of a successful restoration of a species-rich sward were high.

Spreading seed using a quad-bike mounted fertiliser/seed hopper. © RNRP

Preparing strips of the ground with a tractor and harrow (spring tine or similar). © RNRP

Techniques
In September 2014, six 150 m x 6 m strips were lightly cultivated, seeded and then rolled in one half of the site. The strips were separated by 12 m and were located so as to give a range of different soil and water conditions. The strips were seeded with a commercial seed mix (Emorsgate EM8). As the site already had a good diversity of grasses, the seed mix contained herb seeds only. Known patches of great burnet were avoided. The work was carried out by the farmer using standard farm machinery. The second half of the meadow was scheduled to be treated in spring 2015, followed by the reinstatement of hay-meadow management, with grazing until no later than mid May and a July hay cut, earlier than previously.

Monitoring
In summer 2014, fixed-point botanical monitoring along a transect was carried out to provide baseline data, and will be repeated as the project progresses.

Cost
The cost of the seed (approx. £6,000) was covered by the NIA. The meadow is in HLS option HK15 "maintenance of grassland for target features", but Natural England will review the option over the next couple of years.

Partners
Nene Valley NIA (lead partners – Wildlife Trust BCN, River Nene Regional Park), the farmer, Natural England.

Benefits

- Enhanced public views of the flower-rich meadow from the historic castle.
- Increased biodiversity.
- Improved habitat for pollinators in a largely arable landscape.

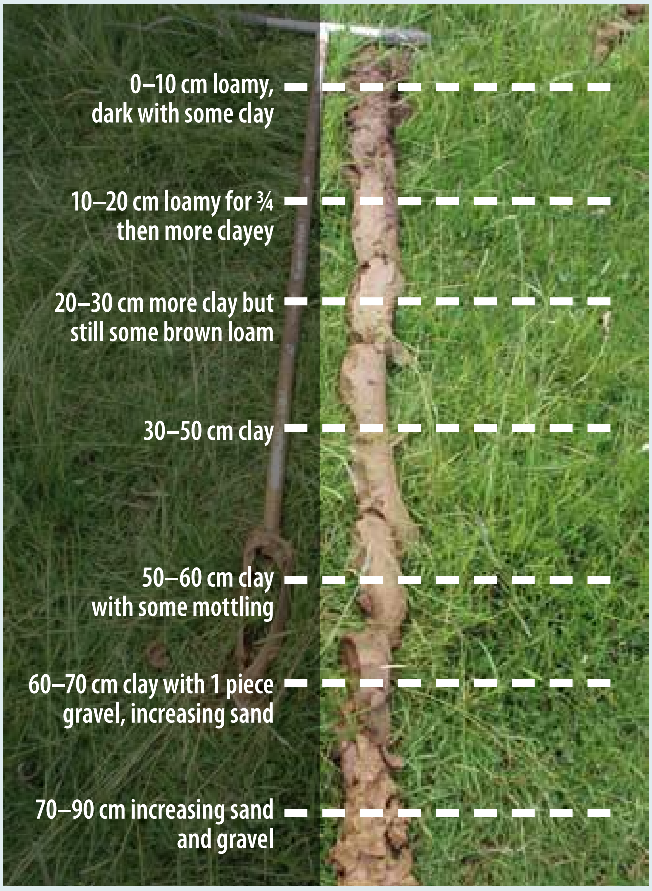

Figure 10.3 A soil core taken from Fotheringhay Meadow showing the soil profile. © Heather Proctor

CASE STUDY 10.2
Piddle Brook Meadows, Worcestershire – change from pasture to meadow management on a site with some floodplain-meadow indicator species present

About the site
Piddle Brook Meadows was purchased from the Naunton Court Estate in August 2009 by Worcestershire Wildlife Trust (WWT). The 7 ha site lies within the Forest of Feckenham Living Landscape area and is adjacent to Worcestershire Wildlife Trust's Naunton Court Fields reserve.

The meadows have had a mixed-management regime in the past, including silage cuts in May, and spring horse grazing on the drier ground. There is a small area of ridge and furrow on the western boundary of the site, which has been designated as a Local Wildlife Site. It is not known whether artificial fertiliser has been applied in the past, but although there is a good diversity of grass species, herbs are lacking from large areas. The Piddle Brook has been deepened and several pollution incidents have occurred in the past. The site floods in winter and more recently summer flooding has occurred, but water drains from the site effectively. WWT wished to increase the floristic diversity within the sward.

Technique used
Since the project began in 2010, hay cuts have been taken in late June followed by aftermath grazing with cattle and sheep in late summer and autumn under an HLS agreement. If results proved poor after five years under this regime, the plan was to spread green hay from a similar nearby reserve.

Monitoring
- Fixed transects and NVC survey (2011 and 2014).
- Soil pH and nutrient status.

Results
The NVC survey showed a grassland strip that is a 'hybrid' of Cuckooflower grassland (MG15p) and the species-poor Creeping bent sub-community of Burnet floodplain meadow (MG4d), although one of the main community constants, great burnet, is missing and has not been previously recorded here.

These findings justify the restoration programme currently being put into operation as the management has maintained the cover of meadowsweet, a dropwort and other MG4 associates, but has not increased their abundance or extended their distribution across the site. The next phase should be to consider whether to bolster the diversity from year six (2016) onwards by spreading hay or seed from a nearby compatible donor site, at least on a small trial area.

Cost
After the initial cost of purchasing the site, erecting fencing and installing a water supply, site management costs are for 3–5 person days per year. Two volunteer work parties per year carry out pollarding and hedge/scrub management. These have on average, ten people per work party at £50 per day plus one day of staff time. Income is generated through renting the grazing, the HLS agreement and sale of the hay.

Partners
Worcestershire Wildlife Trust with Natural England through HLS agreement.

Benefits
- Increased offtake of nutrients from catchment through removal of hay crop.
- Increased public access to flower-rich meadow.
- Increased biodiversity.
- Enhancement of Piddle Brook corridor and Feckenham Forest Living Landscape (connectivity).

CASE STUDY 10.3
Chimney Meadows, Oxfordshire – reduction of high P levels through an annual hay cut and aftermath grazing

Chimney Meadows are a National Nature Reserve and SSSI owned and managed by BBOWT (Berkshire, Buckinghamshire and Oxfordshire Wildlife Trust). In 2004, BBOWT bought 70 ha of arable land adjacent to the NNR and planned to restore it to species-rich floodplain meadow through green-hay spreading, using green hay from the adjacent species-rich NNR. As part of the project plan, soil analyses were undertaken including P data from all the fields. Two of the fields recorded P indexes of 4 (46–70 mg/l^{-1}) which is outside of the range considered suitable for floodplain-meadow restoration. The others recorded P indexes of 3 or below. The index 4 fields had been previously sown with winter wheat or spring barley.

To prepare these fields for green-hay spreading, sheep were used to graze grass and weeds that had grown amongst the stubble, any remaining vegetation was sprayed with the herbicide glyphosate, dead vegetation was topped and the soil was then disc-harrowed to turn dead vegetation into the soil and to create a seed bed.

Green hay collected from the NNR was spread across all the fields at a ratio of 1 ha of green hay cut spread across 3 ha of receptor field. The spread material was then rolled and left to germinate. Follow-up management involved topping the vegetation to a height of 10–15 cm to keep the sward open and encourage germination of other plants, and then annually hay cutting and aftermath grazing once a sward was established.

On the P index 4 fields, a thick grass sward grew very vigorously with few herbs. After hay cutting, grazing and weed topping for ten years, the sward now contains species indicative of lower fertility swards, including cowslip, common knapweed, fairy flax and pepper-saxifrage.

CASE STUDY 10.4
Wheldrake Ings, Yorkshire – water-level management for birds and meadows

About the site
This 157 ha site was purchased by Yorkshire Wildlife Trust (YWT) in 1973, when it was still used for hay making. Anecdotal evidence from farming families suggests that the good quality hay meadows spread much further into the central (lowest) part of the site than they do today. Botanical records from the 1970s suggest that Burnet floodplain meadow (MG4) indicator species (great burnet, meadowsweet and pepper-saxifrage) were previously more extensive.

After the site was purchased, sluices were installed in the two main ditches draining into the River Derwent, allowing the fine-scale management of water levels. At the time, water was held on the site in winter and spring to try to attract more bird life. Before this, water flowed freely on and off the Ings. Over the last several decades, the focus of the management at the reserve has swung from birds to botany and back again. The site is designated an SPA for wintering, passage and breeding birds, and an SAC for floodplain-meadow grassland. It is also an SSSI and an NNR[42].

Much of the site drainage is controlled through a network of grips and ditches, with two sluices controlling flow into the Derwent. Water will only flow out of the ditches when water levels in the Derwent are low enough, as the sluices are gravity controlled.

Funding
The reserve is managed mostly under Farm Business Tenancies and annual tenancies to the local farmers who cut and graze it. It is currently in an HLS agreement with much of the land managed through contracted farmers, and YWT graze part of the site. YWT then tries to supplement this with external funding bids.

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[42] See page 21, Chapter 4 for a definition of designations.

Project objectives

1. To increase the area of Burnet floodplain meadow (MG4), which is believed to have decreased in the last 50 years, by lowering winter and spring water levels.
2. To balance the needs of the plant communities with those of the wintering and passage birds and to ensure the bird populations are maintained.

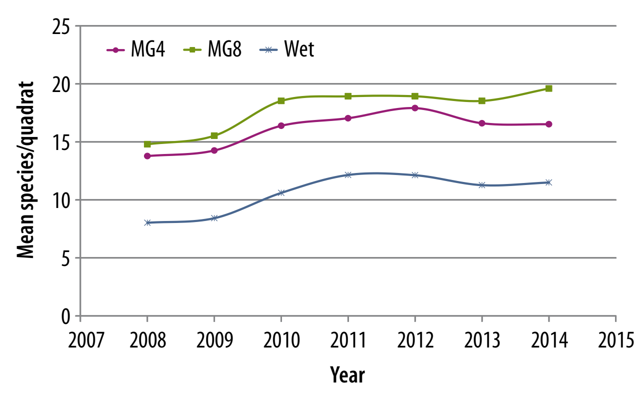
Technique used

A trial management regime was put in place, initially for five years. This was based on advice from wetland experts David Gowing and Neil Humphries, who suggested that Burnet floodplain meadow (MG4) cannot stand prolonged inundation, but that a water level of about 40 cm below the surface of the ground during the growing season could be tolerated, with the vegetation being less susceptible to waterlogging during the winter.

Ground-level contours for the Ings were investigated to explore the likely area of winter inundation under different scenarios. A sufficient drop in water level was needed to expose an area big enough to be worthwhile for floodplain-meadow restoration, whilst also leaving enough open water to support the tens of thousands of wintering birds that use the reserve. The area chosen is adjacent to the existing floodplain-meadow plant communities, so local seed sources and plants should colonise the restoration area. Further advice was sought from Natural England on how to make these changes without significantly affecting the birds on site. The trialled solution is as follows:

Winter: when river levels allow, the sluices are opened and water drops down to 40 cm below the 'sill level', revealing a 'band' of land where Burnet floodplain meadow (MG4) can re-establish itself. In practice, however, this rarely happens as the river water levels are too high so water cannot leave the site.

Figure 10.4 Change in species richness for permanent monitoring quadrats between 2008 and 2014 at Wheldrake Ings, Yorkshire. 'Wet' refers to those quadrats falling within NVC communities of the OV and S categories.



Spring: the draw-down of water continues so that the water table reaches its 'summer level' by mid May. By the end of May there is no standing water, only occasional pools for passage birds. The higher areas of the site should be dry enough, early enough, for the re-establishment of Burnet floodplain meadow (MG4).

Summer/autumn: a cutting and grazing regime is followed to suit Burnet floodplain meadow (MG4) restoration, and good relationships have been developed with tenant farmers to ensure that this management takes place. There is more reliable grazing now possible through the capital HLS fencing installation.

Monitoring

- Seventy-two fixed-point quadrats are surveyed annually by the Floodplain Meadow Partnership (FMP). One line of 20 quadrats was first recorded in the 1970s with repeat surveys conducted in 2002 and 2006.
- Dipwells with automated readers were installed and are downloaded annually by FMP, which also collects soil-fertility and hay-quality data.
- Wetland Bird Survey (WeBS) counts and Breeding Wading Bird Surveys are carried out by Natural England.
- NVC surveys 2003, 2008, 2014.

Results

Overall species richness increased most between 2009 and 2010; however, despite the lowered water levels, it is clear that the species-richness of the swamp and OV vegetation communities also continued to increase between 2010 and 2011. This may be due to drier soils allowing increased cutting of these wetter areas, leading to a reduction in shading by a few more bulky species, such as reed canary-grass. Regular cutting of the wetter areas is likely to maintain these increases in species-richness. Overall species-richness peaked in 2012 following the relatively dry winter and summer of 2010–2011. The wet summer of 2012 resulted in a small decrease in species-richness in 2013, especially in the drier Burnet floodplain meadow (MG4) vegetation. However, species-richness in 2014 was significantly higher than at the start of the trial in 2008. The slow draw-down in spring leaves valuable pools for passage birds and is of particular benefit to whimbrel travelling through the Lower Derwent Valley.

Cost

Approximately £12,000 per year plus staff and volunteer time.

Partners

YWT, Natural England.

Benefits

Increased area of species-rich floodplain meadow. The combination of water-level management, better relationships with tenants, greater areas being cut and regular ditch maintenance has all helped to achieve this. However, the habitat has shown itself to be very sensitive to weather-pattern fluctuations year on year.

CASE STUDY 10.5
Seighford Moor, Staffordshire – changing ditch-water levels to retain species-rich plant communities

Seighford Moor is a 40 ha Local Wildlife Site in Staffordshire. It is owned by a nearby estate and leased to a tenant farmer. About a quarter of the site is occupied by floodplain meadows, which are managed with a hay cut followed by aftermath grazing. The site has been farmed by the same family for at least 50 years, and has a long history of consistent use. The site is managed through an HLS scheme.

The potential of the site as a Local Wildlife Site and floodwater storage area was recognised in 2007 by the 'Farming Floodplains for the Future' Staffordshire pilot project. Under this project, and supported by agri-environment scheme funds, water-control equipment was installed in 2009 in order to 'wet the site up', focusing on the less species-rich areas of the site for the benefit of wading birds.

A visit from the Floodplain Meadows Partnership in 2010 identified that the species-rich areas were changing towards swamp communities as the raised water levels and recent high rainfall started to take effect. Staffordshire Wildlife Trust (SWT) commissioned a botanical monitoring programme to assess the long-term effects of hydrological manipulation on the flora of the meadows, and in summer 2011 an NVC survey of the meadows showed that some of the hay meadows were Kingcup-carnation sedge meadow (MG8), and some small areas were similar to the Yorkshire fog sub-community of Burnet floodplain meadow (MG4). The overall assessment was that the site was being kept wet for 6–8 weeks too long per year and that the water-control structures should be opened or removed to reduce waterlogging of the surface soil.

Technique used

The water-level control structure closest to the species-rich meadow area of the site was removed in late 2010. Monitoring was instigated to assess the stability of the vegetation at the site and to relate species and community distributions to the soil-water regime.

Figure 10.5 NVC map for Seighford Moor species-rich hay meadow area with dipwell locations.

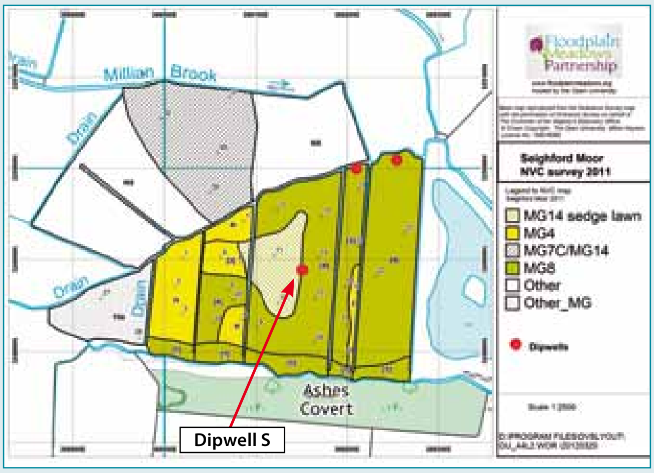
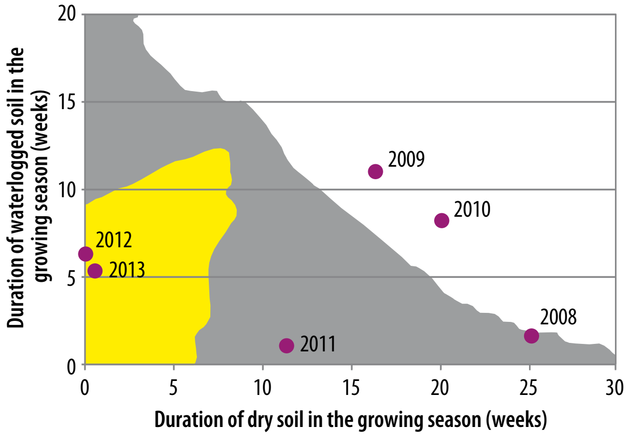


Figure 10.6 The expected hydrological range for Kingcup-carnation sedge meadow (MG8) is shaded yellow compared to the hydrological range for all species-rich grasslands shaded grey. Annual hydrological regimes from recordings of Seighford Moor's Dipwell (S) in the period 2008–2013 (see Figure 10.5) have been plotted to show the duration of wet and dry soils during the growing season.



Monitoring

In 2010, some botanical monitoring was undertaken and in June 2012 a series of 54 botanical transects were established. SWT installed a series of dipwells to monitor the effects of the ditch level controls.

Results

A review of the dipwell data from 2011 to 2013 shows that the water levels were within the expected range for Kingcup-carnation sedge meadow (MG8).

Figure 10.6 illustrates the degree to which management can affect hydrology. This site was relatively dry prior to 2008, as typified by the 2008 spot showing that 25 weeks of the growing season had water tables deep enough to cause little impact on the surface soil. The ditch levels at the site were artificially raised in 2009, producing a regime that gave around ten weeks of waterlogging during the growing season, as indicated by the 2009 and 2010 spots. This hydrological regime proved to be beyond anything previously recorded for species-rich grassland, which is represented by the grey zone in the figure. In response to this information, ditch levels were allowed to fall again, producing the moist, but not heavily waterlogged regime of 2011, which was a dry year weather-wise. The years 2012 and 2013 were very wet in terms of rainfall and their hydrological regimes as plotted on the figure show them to fall clearly into the preferred hydrological niche of Kingcup-carnation sedge meadow (MG8) (represented by the yellow zone).

Quadrat data from 2011, 2012 and 2013 were used to assess changes in the goodness-of-fit to NVC communities.

The dipwell (S) from which the data plotted in Figure 10.6 are derived sits in a low-lying area of Sedge lawn (MG14) surrounded on the drier margins of the field by typical Kingcup-carnation sedge meadow (MG8) (see Chapter 8). The sward in the field to the west represents an excellent example of the Burnet sub-community (MG8a) of Kingcup-carnation sedge meadow (MG8D), which is usually associated with rather drier soils than the Typical form or the Sedge lawn (MG14). The botanical monitoring data from this area indicated that the vegetation was stable in NVC terms, with no expansion of large sedge species.

The fields to the east of dipwell (S) supported species-poor Kingcup-carnation sedge meadow (MG8) in 2011 and subsequently showed an increase in species diversity and improved goodness-of-fit to Kingcup-carnation sedge meadow (MG8), with a reduction of rush cover and increases in common sedge, tufted hair-grass, ribwort plantain and clover species, suggesting a move to a drier community.

Cost

No cost for change in management as this was simply removal of the sluice board, carried out by the Farming Floodplains for the Future project. Monitoring equipment (automated recorders, dipwells, installation and analysis) was approximately £4,500.

Partners

Staffordshire Wildlife Trust, Natural England, Floodplain Meadows Partnership, landowners, tenants of the Seighford Estate and the Sow and Penk IDB (Internal Drainage Board).

Benefits

Retention of species-rich plant communities. Entry of site into HLS scheme and designation of site as a Local Wildlife Site.

CASE STUDY 10.6
Swill Brook Meadow, Lower Moor Farm complex, Wiltshire – introducing green hay to a species-poor grassland

About the site

Swill Brook Meadow (2.86 ha) is a component of the Lower Moor Farm complex of nature reserves purchased by Wiltshire Wildlife Trust between 1996 and 2005. Swill Brook Meadow links directly to Clattinger Farm (also part of the complex) which is an SAC (see Chapter 4) for its high-quality floodplain-meadow vegetation. Although very species-poor in comparison to the SAC, Swill Brook Meadow was less agriculturally improved than the remainder of the Lower Moor Farm fields.

Together with the rest of Lower Moor Farm, Swill Brook Meadow had a history of year-round grazing by cattle and sheep. It is very wet in winter and has a tendency to flood, so is likely to have escaped the heaviest winter-grazing pressure.

In 2010 the Lower Moor Farm complex was entered into an Environmental Stewardship (ES) agreement and Swill Brook Meadow was identified as a suitable location for sward enhancement in order to extend the area of good quality floodplain-meadow habitat.

Technique used

The management option chosen was sward supplementation with green hay due to the on-site availability of suitable species-rich grassland from which green hay could be harvested. In late July 2010, the meadow was cut tight to the ground. A spring tine harrow was used to break up the sward and create bare ground by pulling out the remnant thatch and any dead vegetation lying on the soil surface (thus ensuring that seeds in the green hay were able to reach the ground to germinate).

At Swill Brook Meadow the area of bare ground created was less than the recommended 40–50% because of the presence of species of interest including low numbers of snakeshead fritillary. The green hay was cut and big-baled in nearby Oaksey Moor Farm Meadow and transported 500 m to Swill Brook Meadow where it was spread within a few hours using a straw spreader. The ratio of donor to receptor area was a little less than 1:3. After spreading, the meadow was left to settle for a few weeks, then grazed lightly by sheep. Sheep were used because the underlying Oxford Clay soils are vulnerable to poaching in wet conditions.

The bale is loaded into the rear of the spreader, chopped and then spread over the grassland through a funnel. The angle of the funnel and flow rate are adjustable, allowing the depth of the green-hay layer and the area of distribution to be altered. This method is quick and efficient. © Catherine Hosie

Following green-hay application, the meadow has been managed with a hay cut after 15 July, depending on weather conditions. Traditionally the hay cut was an extended process carried out over several weeks by hand or with small agricultural machinery. In the species-rich fields at Lower Moor Farm this extended hay-cutting process continued until the late 1990s when the farmer retired. Using modern farm machinery, hay cutting can now be completed within a matter of hours and as high nutrients are not a problem at Clattinger Farm, a later cutting date tries to replicate the traditional management at the site. This management is supported by the HLS option within the existing ES agreement. Aftermath grazing is carried out by cattle, which graze a number of the fields together, until the ground becomes too wet. If not cut for hay, the meadow may be extensively cattle grazed during the summer.

Monitoring

Ten 1 x 1 m quadrats were set up adjacent to Swill Brook Meadow on Side Ham to provide data from a sward that had not been enhanced for comparison and was already species rich. Three groups of five quadrats were established on Swill Brook Meadow to look at the impact of the green-hay intervention.

Figure 10.7 Mean species number per m^2 for each field between 2010 and 2014.

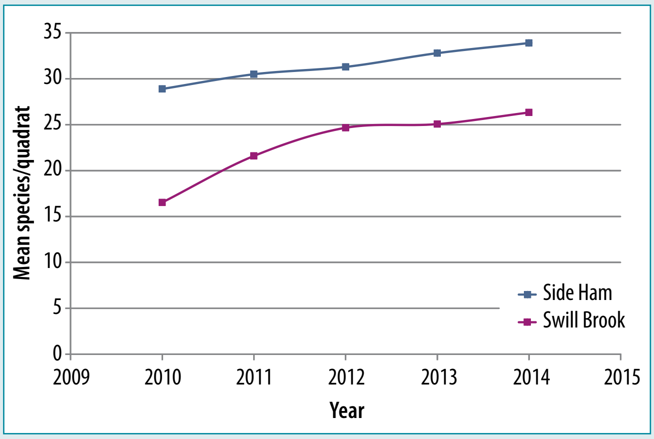
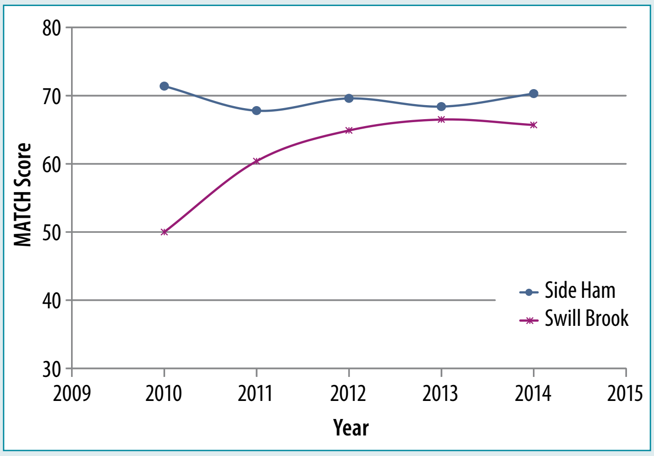


Figure 10.8 Change in the goodness-of-fit to the Burnet floodplain meadow community (MG4) of Rodwell (1992) of Swill Brook and Side Ham between 2010 and 2014. Scores are Czekanowski coefficients of similarity calculated using the MATCH program (Malloch 1998). Values are based on constancy tables derived from sets of ten quadrats in Side Ham and 15 quadrats in Swill Brook.



Results
The monitoring programme indicates that the work at Swill Brook Meadow is successfully recreating a species-rich sward referable to the Burnet floodplain community (MG4). In 2011, just 12 months after the green-hay application, species-richness had increased significantly, as had the goodness-of-fit to the target floodplain-meadow community. The transformation from species-poor Cuckooflower grassland (MG15p) to the more herb-rich Burnet floodplain meadow (MG4) continued in 2012 with further recruitment and expansion of species. Moss cover has also increased whilst the cover of species of more improved mesotrophic grasslands, such as perennial rye-grass and white clover has continued to decline. Changes in 2013 and 2014 were more modest, but the field is now similar in its species-richness to other Burnet floodplain meadow (MG4) fields in the reserve (see Figures 10.7 and 10.8).

Costs
Minimal as machinery used belonged to the Trust and green hay was collected and spread from Trust-owned adjacent fields.

Partners
Natural England through HLS agreement.

Benefits
Creation of 2.86 ha of species-rich meadow, additional hay crop, buffer for existing species-rich meadow.

CASE STUDY 10.7
Boddington Meadow and Kingsthorpe North Meadows, Northamptonshire – wildflower seed collection by brush harvesting for use in restoring floodplain meadows

About the sites
Boddington Meadow is a 2.3 ha Wildlife Trust for Bedfordshire, Cambridgeshire and Northamptonshire reserve and Local Wildlife Site with areas of Burnet floodplain meadow (MG4). The site is particularly herb-rich and also has a good range of grasses. Never ploughed, a wet meadow on the edge of a reservoir provides an impressive display of colour, with great burnet, betony and devil's-bit scabious. The site became a Trust reserve in 1986 and has been managed through a late hay cut and light aftermath grazing ever since. It became the county's Coronation Meadows in 2013.

Kingsthorpe North Meadows (as opposed to Kingsthorpe Meadow, Chapter 9) is a 4.5 ha site with a mix of drier ridge-and-furrow and wetter floodplain meadow, and has been owned by the local community since 2009. It is situated on the banks of a tributary of the River Nene. A small wetland section in the northern end became a Local Wildlife Site in 2005. The site is managed through an annual hay cut. Soil samples showed low nutrient levels and the upper slopes have already been restored to a semi species-rich grassland through management. The lower sections are species-poor, with a range of grasses, and regularly flood during the winter. The project aims to restore the lower area to a species-rich floodplain meadow. P levels of 12 mg/l^{-1} indicate that this should be feasible.

Technique used
Donor site
Boddington Meadow was chosen as a donor site as it has similar soil and hydrological conditions to Kingsthorpe North. A low-impact brush harvester was used to collect the seed. This had a rotary brush with stiff bristles, designed to sweep the seed heads it comes into contact with into the hopper, and was pulled by a compact tractor.

Seed harvesting was undertaken on two occasions (mid July and late August). Additional great burnet and devil's-bit scabious seed was collected by hand. Seed was collected from around one-sixth of the site on each visit across roughly spaced sets of strips, meaning seed was collected from around a third of the site in total.

The seed was bagged and most was taken straight to an agricultural contractor to be dried using a seed drier, while the remainder was spread out and dried on a barn floor.

Receptor site
Kingsthorpe North Meadows were cut short in early August. Several 6 m wide strips were created by shallow rotavation with the aim of creating open ground on one-third of the site. The collected seed was hand-sown into these strips, and the strips were then rolled. The plan was to top the strips the following year to help control weed growth. A shallow drain running through the field was re-dug to help drain the topsoil.


Seed harvesting at Boddington Meadow using a brush harvester. © River Nene Regional Park RNRP

Monitoring
Boddington: quadrats were undertaken along fixed transects to assess impact of seed collection in the year following collection, then every three years.

Kingsthorpe: quadrats were undertaken along fixed transects to monitor the restoration on an annual basis.
Monitoring results for the two sites are not yet available.

Cost
- Seed collection: £200.
- Rotavation and rolling: £380.
- Ditch works: £760.
- Most of the labour was through staff time and volunteers.

Partners
Wildlife Trust BCN, with Nene Valley NIA, Kingsthorpe North Meadows Trust, Coronation Meadows and Biffaward.

Benefits
- Increased offtake of nutrients from catchment through removal of hay crop.
- Creation of 4.5 ha of flower-rich pollinator habitat.
- Buffering of wetland Local Wildlife Site.
- Increased public access to flower-rich meadow.

CASE STUDY 10.8
Broad Meadow, Northamptonshire – converting an arable field to a floodplain meadow

About the site

Broad Meadow was species-rich floodplain meadow until the 1970s, when the farmer gave up dairying and converted to arable. The fields were used for arable production until 2007 when the last crop of oilseed rape was harvested. During this time artificial fertiliser was used as required. The field floods from the river each autumn and spring.

Technique used

Soil analysis undertaken in August 2007 showed that phosphorus levels were on the upper edge of the expected range for a species-rich floodplain meadow (phosphorus 16 mg/kg^{-1}, potassium 96 mg/kg^{-1}, magnesium 129 mg/kg^{-1}, pH 6.3). Emorsgate Meadow Seed Mixture for Wetlands (EM8) was chosen on the basis of the soil fertility and hydrological conditions, and included 17 wildflowers and seven grasses.

The seed was sown at 3 g/m^2 in April 2008 after the field had been ploughed and rotavated. A small section that had not been used for arable cropping was treated with the herbicide glyphosate. After sowing, the meadow was cut four times during the first six months. No grazing took place in the first year.

In 2009 a hay cut was taken. The cut was timed to remove the maximum amount of nutrients, and took place on 30 June. It was baled on 2 July, making 242 large bales from approximately 7 ha.

Ongoing management

The meadow is cut for hay annually during June or July and is then grazed by sheep and/or cows until late autumn. The farmer cuts and bales the hay and then sells it. A grazier provides livestock for aftermath grazing.

Monitoring

- A botanical survey using ten 1 x 1 m quadrats, 15 m apart is carried out in June each year by surveyors from the Wildlife Trust for Bedfordshire, Cambridgeshire and Northamptonshire and the River Nene Regional Park. The abundance of all plant species is recorded.
- A butterfly transect is undertaken by the farmer's wife once a week from April to September (as per UKBMS[43] criteria).

Results

Species-richness

At Broad Meadow there has been little change in mean species-richness between years since the start of the trial (see Figure 10.9). However, this does not mean that there have not been substantial changes in the composition of the vegetation, as the balance of species has changed.

Goodness-of-fit to NVC communities

The degree of similarity with NVC communities was calculated using the MATCH programme for:

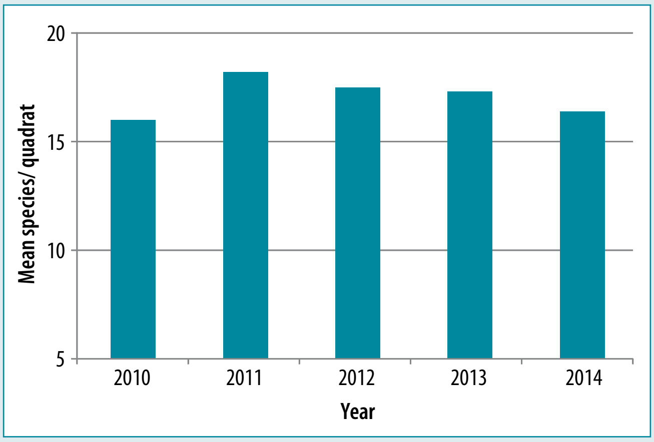
- the species list of the seed mix (2008 values);
- a species list for 2009 (no constancy values were available for that year);
- constancy tables based on ten quadrats recorded each year between 2010 and 2014.

The progression of the sward towards Burnet floodplain meadow (MG4) community can be seen in Figure 10.10. The MATCH score is approaching 60, which is generally considered as representing an acceptable level of agreement.

The prepared seed bed at Broad Meadow. © RNRP

Broad Meadow in 2012. © RNRP

Figure 10.9 Species-richness (the mean value based on ten quadrats) over time at Broad Meadow, Northamptonshire.



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43 UK Butterfly Monitoring Scheme: www.ukbms.org/Methods.aspx

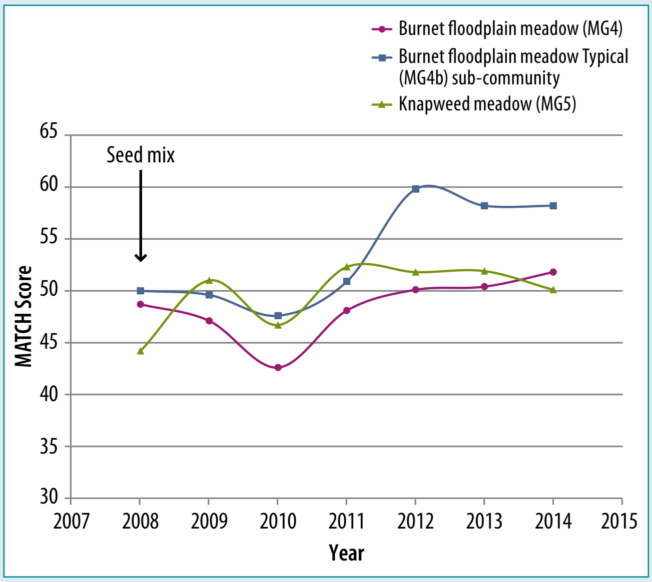


Figure 10.10 MATCH Scores for the seed mix applied in 2008, a list of species recorded in 2009 and constancy values for species recorded in ten quadrats annually between 2010 and 2014 at Broad Meadow, Northamptonshire.

The restoration has been so successful that the site has now been designated as a Local Wildlife Site and several site visits have been conducted with other interested farmers, which have led to another 100 ha of species-rich meadow restoration being undertaken.

Costs

Covered by Natural England's Higher Level Scheme and the landowner.

- Seed: £16,000.
- Fencing and new hedges: over £15,000.
- Ongoing management and creation of new permissive path: approximately £4,500 per year for ten years.

Partners

Natural England, River Nene Regional Park CIC and Mr and Mrs Banner (landowners).

Benefits

- Reduced nutrient inputs to River Nene from cessation of artificial fertilisers.
- Increased offtake of nutrients from Nene catchment through removal of hay crop.
- Economic benefit through sale of hay and grazing.
- A new permissive path increases public access.
- Creation of 7 ha of flower-rich pollinator habitat.
- Creation of a demonstration and discussion site.

CASE STUDY 10.9
Oundle Lodge, Northamptonshire – floodplain-meadow creation from the landowners' perspective

Oundle Lodge restoration project is found at Big Meadow, a 10 ha field along the River Nene in Northamptonshire. Previously an arable field, it floods most years resulting in nutrient, pesticide and soil loss and poor crop yields.

The farm is a mixed farm with other riverside meadows and so was able to expand the livestock (beef) enterprise element. The farmer's father was very interested in the environment and in the 1970s and 1980s created new habitats on the farm, and so the project focused on creating further wildlife habitat in addition to managing the site in line with environmental factors.

The farmer already had the equipment and livestock to manage the fields for hay, including aftermath grazing. However, the farm did not have the appropriate physical infrastructure for grazing the restoration fields. The plan drawn up for the Higher Level Scheme over the ten years of the agreement therefore included fencing, gates and cattle drinking points. It also included the use of native-breed cattle.

A Wet Grassland Mixture from Emorsgate seeds (EM8) was used to re-seed the field as no donor sites for either seed or hay were available. This mix had proved to be very successful elsewhere along the River Nene (e.g. Broad Meadow in Upper Heyford in 2008). It was sown at 3 g/m^2 in the autumn of 2010 and cut four times in 2011. In 2012, spot spraying was carried out to control docks and the hay was cut at the start of July to remove nutrients, and aftermath grazed. This management has continued.

This creation scheme was funded by Natural England's Higher Level Scheme at the following rates:

- ELS payments: £30/ha.
- HLS payment for the creation of species-rich grassland: £280/ha.
- HLS payment for hay making option: £75/ha.
- HLS Payment for native breeds at risk grazing supplement: 70/ha.

Capital works

- Fencing: £2.50/m.
- Gates: £149 each.
- Cattle drinking bays: £119 each.
- Native seed mix: £1,400/ha.

As a result of the project, a number of considerations for advisors were drawn up in discussion with tenant farmers and landowners, and are listed in Table 10.5.

Table 10.5 Factors for advisors to consider in planning creation and restoration projects.

Farmer/business needs and opportunities	Planning considerations	Machinery and stock considerations
Managing the business in the most profitable way	Ensure the case for re-creation or restoration is financially sound	Mixed farms may already have the right stock and machinery
Matching the available resources and skills with current enterprises	Check that suitable infrastructure is either in place or is attainable	Arable-only farms may struggle to manage a floodplain meadow in the long term
Expanding or starting an enterprise	Check that the landowner has the means to manage the site in the long term	Intense grassland management is needed in the first year of creation projects
Benefiting the environment	Explore creation/ restoration options	Increased weed control may be needed for the first five years on certain sites
Possibility of taking a hay crop on sites that fail to support more intensive crops due to annual flooding		The use and number of livestock needs to be closely monitored over the first five years

CASE STUDY 10.10
Priors Ham, Wiltshire – changing from pasture to hay-meadow management where water regime and nutrients were appropriate but indicator species scarce

About the site

Priors Ham is a small (4 ha) meadow adjacent to North Meadow National Nature Reserve. In 2008, survey work carried out by the Floodplain Meadows Partnership indicated that the site had potential to be restored from species-poor pasture to species-rich meadow. The soil-fertility status and soil-water levels were within the range suitable for Burnet floodplain meadow (MG4) and the meadow was entered into an HLS agreement for restoration and enhanced public access.

Technique used

In 2010, the meadow was sprayed twice with a glyphosate weedkiller prior to spreading with brush-harvested seed. For comparison, a small area was also spread with green hay in early August, following a single application of weedkiller earlier in the year. In 2011 the seeded area was sown again with brush-harvested seed collected from North Meadow by Emorsgate Seeds and grazed lightly. No other management was undertaken that year. Particularly wet conditions in 2012 prevented both hay cutting and any further interventions (treatment for docks and oversowing with brush-harvested seed in the green-hay area). In 2013 the field was 'topped' to cut the weeds, then cattle grazed. An early hay cut was taken in 2014 to try to re-balance the nutrient influx from the extensive floods of 2012/2013 and grazed once again.

Monitoring

Two blocks of five quadrats were surveyed in 2010 prior to the restoration work, one block in the green-hay area and the other in the seed-treatment area. These were re-recorded annually in 2012–2014. Two dipwells were installed with automated data loggers to monitor water-table levels. Soil samples were collected at two locations, pre- and post-restoration work. An adjacent field, Lake Meadow was also monitored and acted as a control throughout the trial.

Results

At Priors Ham, species-richness had more than doubled by 2012, although many species were present at low cover and great burnet had not colonised. In 2013, there was a marked decline in richness following a long period of flooding in 2012–2013. By 2014, Priors Ham was showing recovery from the flooding, and although species-richness remained below that of the 2012 peak, both areas were significantly richer than at the start of the trial and richer than the unseeded Lake Meadow, which showed very little change over the monitoring period (see Figure 10.11).

Priors Ham in 2015. It may take a while to see a really species-rich meadow here, but the management is now right and species diversity is increasing. © Mike Dodd

Data from the two soil samples showed high pH (7.4 and 7.6) similar to that found in much of the adjacent North Meadow. However, the values for available phosphorus (41.7 and 56.0 mg/l^{-1}) were much higher than the range suitable for Burnet floodplain meadow (MG4) community and were higher than at the start of the trial, presumably because of the extensive flooding in 2013–2014 (see Figure 10.12). The depth and duration of spring flooding was quite limited in both 2011 and 2012, with water levels falling to 50 cm below ground during summer 2011 and between late April and early May 2012. However, the summer rainfall in June 2012 resulted in almost continuous surface water across the meadow from July 2012 until early May 2013.

Figure 10.11 Changes in species-richness at Priors Ham and Lake Meadow 2010–14. Lake Meadow (S) and (N) are two blocks of quadrats in the control field.

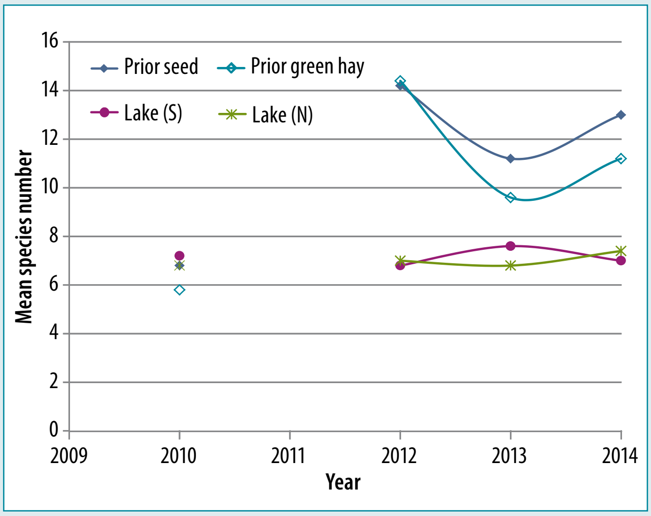
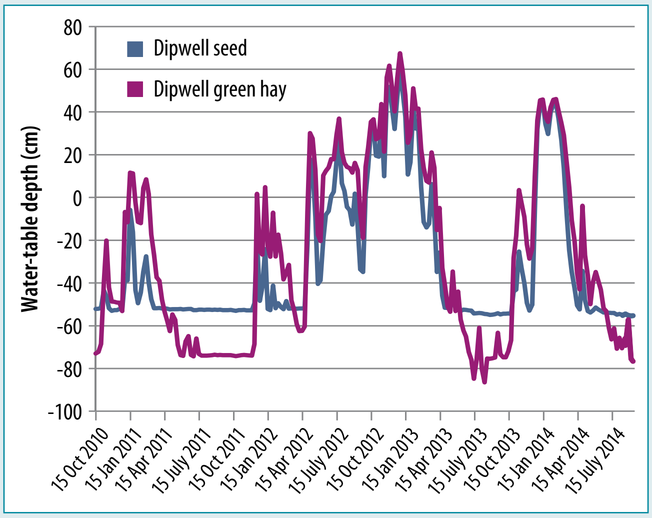


Figure 10.12 Hydrographs for the two dipwells in Priors Ham. Negative values indicate the depth of water table below the surface; positive values indicate the depth of surface floodwater.



Cost
The initial costs of approximately £1,300 were made up of:

- ground preparation (including weed control and cultivating);
- costs of getting area in North Meadow brush harvested;
- drying and storing of seed; and
- sowing of seed (labour, machinery and sand-mixer costs).

Natural England provided the National Nature Reserve green hay free of charge. The second oversowing cost approximately £500.

Partners
The Co-op group (landowners), the tenant farmer and Natural England.

Benefits

- Increased offtake of nutrients from catchment through removal of hay crop.
- Increased public access to flower-rich meadow.
- Increased biodiversity.

CASE STUDY 10.11
Somerford Mead[44], Oxfordshire – a long-term restoration site with post-restoration management trials. How long does it take?

Introduction

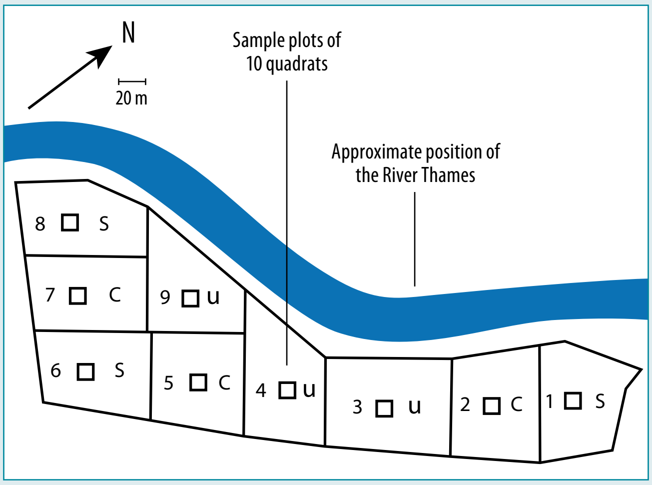
Somerford Mead (6.1 ha), had been Burnet floodplain meadow (MG4) in the 1950s at the University of Oxford's Field Station at Wytham, Oxfordshire. In the 1960s it became sheep pasture and in the 1970s the site was agriculturally improved. It was ploughed for the first time in 1981 and three crops of barley, grown with agro-chemicals were harvested. In 1985 a fourth barley crop was taken specifically to reduce soil fertility. No further chemicals were added prior to a restoration project. A seed-bank study in 1985/1986 looking at plants growing amongst the sown barley determined that no seeds of floodplain-meadow species remained in the soil.

Data collected in 1985 demonstrated that Somerford Mead was situated on circum-neutral (pH 7.5) alluvial soils over limestone gravel of varying thickness.

In 1986, seed from nearby Oxey Mead was harvested by Emorsgate Seeds and spread on Somerford Mead, which was then managed as a hay meadow with a late June/early July hay cut, and aftermath grazing with 12 heifers and 50 sheep. Similar management was undertaken in 1987 and 1988.

In 1989, a replicated block experiment was set up to compare differences between aftermath-grazing treatments of sheep, cattle and no grazing (Figure 10.13). The hay cut and differential grazing continued throughout the experimental period. Monitoring was carried out in the centre of each plot throughout the experiment.

Figure 10.13 Position of different grazing plots with ten sheep (s) in each of three plots, two cows (c) in each of three plots and no grazing (u) in three plots.



Somerford Mead in June 1987. Yellow-rattle has germinated, but the sward is grass dominated and species poor.
© Alison McDonald

Results

Botanical diversity

Germination of sown grasses such as meadow brome, Yorkshire fog, rough meadow-grass and perennial rye-grass was good in the first year (1987) but arable flowers in the seed-bank accompanied the sown grasses in almost equal numbers in the very open sward (Figure 10.14). In 1988, 18 of the unsown annuals recorded during the seed-bank study did not germinate or become established and sown species, such as red and white clover, and crested dog's-tail, increased in abundance. Red fescue, cock's-foot, and meadow fescue appeared for the first time (McDonald 1993).

Great burnet germinated well in the first year after sowing (1987) but many of the seedlings died and the plants that became established were at considerable distances from each other. This plant takes many years to spread vegetatively and typically covers large areas of ancient flood meadows, whilst it is still patchy at Somerford Mead. It may not have thrived in the early years of this experiment because the soil was too dry and warm. It began to increase in numbers in the recording plots in 2001 and by the summer of 2007 a few seedlings and small plants were seen in and out of the recording plots, but the plant is still a long way from being as widespread as it is in Oxey Mead, the seed source site, and other similar grasslands. Similarly, meadow foxtail, was first recorded in 1997. By 2007, when there was more rainfall, its population had increased overall, but plants are still scarce in the recording plots. Even though snakeshead fritillary were recorded on the site for the first time in 2015, after 29 years Somerford Mead does still not reflect the description of Burnet floodplain meadow (MG4) in the NVC or match species-rich sites nearby.

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[44] See McDonald 2012.

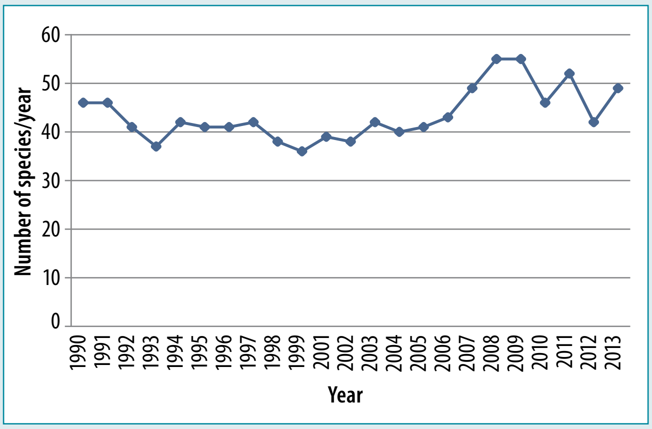


Figure 10.14 The total number of species recorded in the cow-grazed plots over the course of the experiment. The initially high records are due to the mix of arable and meadow species. The drop occurs as the arable species decline, and then the species numbers increase as meadow species develop. Fluctuations in the latter years are related to annual changes in weather conditions.

Phosphate

In 1987, the standing hay was lush and tall and the soil was described as 'requiring no additional nutrients'. By 1990, the soil was already regarded as being of 'low nutrient status'. At this time it was noted that the average pH had increased from 7.7 to 8.7.

Aftermath treatment

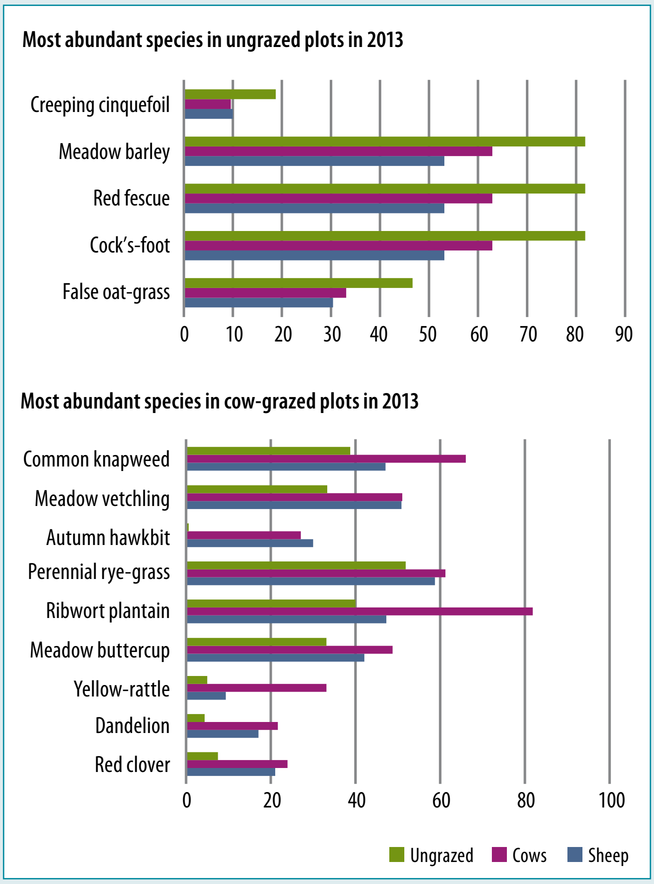
The traditional management of cutting for hay followed by cattle grazing has produced a sward which is a little more species-rich than the sheep-grazed treatments in some years but both of these treatments are richer than the ungrazed plots (Figure 10.15). In 2013, 44 species in total were recorded in both the ungrazed and sheep-grazed plots, and 49 species in the cow-grazed plots.

Invertebrates

As the sward architecture in Somerford Mead became more complex over time it was of increased importance to both the diversity and abundance of invertebrates (which need structures such as stems, leaves, flowers and seed heads for various periods in their life cycle). Since 1993 the cow-grazed plots have become the most suitable for invertebrates including plant-eating beetles (Woodcock and McDonald 2011).

Great burnet at Somerford Mead. © Alison McDonald

Figure 10.15 The cow-grazed plots have a flora more typical of a species-rich meadow, compared to the ungrazed plots, which are typically grass dominated.



Chapter 11
Investigation and monitoring

Emma Rothero and Hilary Wallace

Investigation and monitoring are key elements of floodplain-meadow management and restoration. This chapter explains the importance of these activities and how they are informed by, and help to determine, site-management objectives. Key methods are provided, with information on where to go for further help.

There are many reasons for investigating and subsequently monitoring aspects of floodplain meadows. They are complex and dynamic systems; obtaining relevant information about hydrology and soils will help site managers and others improve their understanding of the way the site functions and how it may have changed. Obtaining accurate information about plants and other groups will help inform decision making about management, while ongoing monitoring will allow the effects of management practices to be assessed and the impacts of external factors, such as changes in water regime, to be identified and planned for.

Figure 11.1 shows the main elements of investigation and monitoring that may be useful on a floodplain meadow. Gathering existing data about the site may include obtaining information on any designations together with copies of relevant citations, collating biological data (e.g. from local record centres, natural history societies, the NBN gateway[45]), exploring historical sources (see Chapter 3), talking to local people and past owners or managers of the site, and studying geospatial data such as flood maps[46], aerial images and, if available, LIDAR[47] data (although this requires technical expertise and appropriate software). Old maps may also be useful, for example in showing where surface drains used to be.

Investigation may also include finding out about characteristics of the site such as the soil profile, texture and structure (see Chapter 4) and the water levels and movement (see Chapter 7) which together provide information on how water moves through the site and will help in understanding differences in the vegetation. Investigation into soil nutrients will be informative, particularly if there are issues with declining species diversity.

In some cases, such information may lead to a change in management practices. For example, if it is discovered that phosphorus levels are high, earlier or second hay crops may be taken; if soils are showing signs of compaction, the grazing regime may be altered and efforts made to decrease the impact of heavy machinery during hay making; while waterlogged soils may indicate the need for increased efforts in gutter, drain and ditch maintenance. Ideally, any significant changes in management will be accompanied by monitoring to establish whether they are achieving the site objectives. This may include monitoring changes in vegetation communities or selected species. Much of this information will also be needed for floodplain-meadow creation and restoration projects – this is explored further in Chapter 10.

Investigation and monitoring need to relate to stated objectives for the site and in some cases will help set and subsequently refine them.

Investigation – the process of obtaining new data about a site, whether through initial survey work or from existing records. Investigatory work will create a baseline dataset for subsequent monitoring.

Monitoring – survey work that provides comparable results over a period of time. It is important to use appropriate and replicable techniques from the start.


Investigation and monitoring also provide learning opportunities, and can be an ideal way for encouraging other people to become involved with floodplain meadows. © Mike Dodd

Methods for investigation and monitoring

There is a wide range of methods for monitoring different environmental variables and taxa. These range from basic methods that anyone with an interest and the time can carry out, to more technical approaches that might require expert support. In some cases, monitoring is just a case of recording information, such as hay yield (number and size of bales), flood frequency and duration, or numbers of grazing animals. Monitoring methods for key features are outlined here, with links to sources of information for monitoring other aspects of floodplain meadows.

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[45] https://data.nbn.org.uk/

[46] http://watermaps.environment-agency.gov.uk/wiyby/wiyby.aspx?topic=floodmap

[47] http://environment.data.gov.uk/ds/survey#/download?grid=SP08

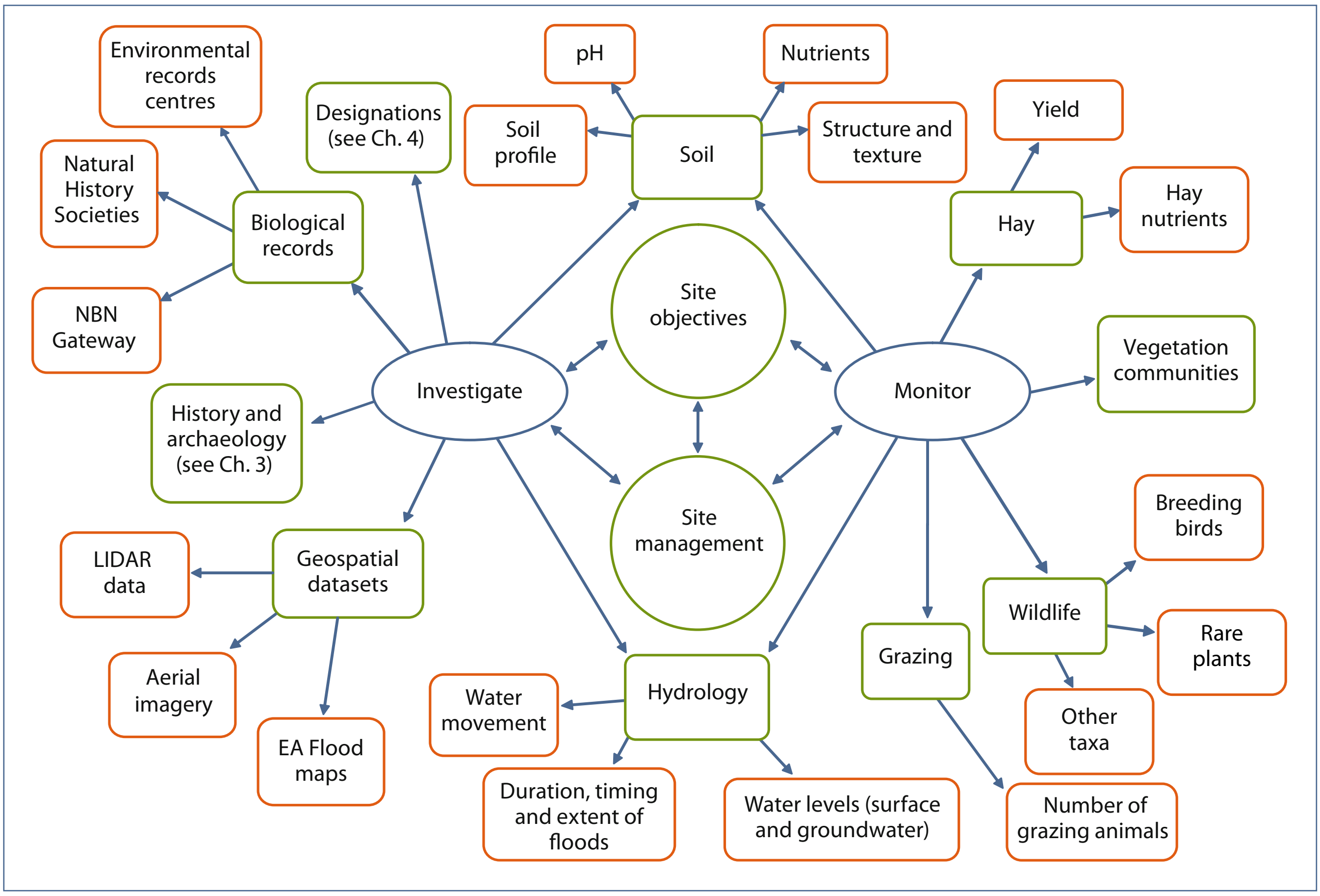


Figure 11.1 Investigation and monitoring on floodplain meadows.

Vegetation monitoring

Changes to plant communities

The most useful way of accurately measuring change over time is by recording the percentage cover of different plant species within several fixed-point ***quadrats*** along a ***transect***.

A quadrat is a frame used to demarcate a given area, for example one square metre. It may be a fixed frame or just pegs and a line of string with loops in the corners, and some means of ensuring the corners are right angles.

The 1 m x 1 m quadrat recommended here is smaller than the 2 m x 2 m recommended in some methodologies, because floodplain meadow vegetation can be very variable due to small-scale environmental and topographical differences; it is also often rich in species. A small quadrat is less likely to combine different vegetation types and is also less time consuming, whilst being sufficiently large to characterise the community.

Key factors in successful monitoring are the consistent use of appropriate methodologies and the systematic recording, storage and analysis of data, together with information about how and when it was obtained. Monitoring data is meant to be used, as well as stored, for future reference!

Long-term datasets (e.g. ten years and over) enable trends over time to be investigated. In the UK, long-term datasets are rare, but very valuable in illuminating cyclic changes and long-term trends. When establishing monitoring methods, these should ideally be considered as long-term projects.

A transect is a fixed line running across the habitat, along which quadrats are placed. Transects are usually laid out along a major environmental gradient, for example running from lower, wetter ground to higher, drier ground. This makes it possible to account for the environmental variability often found in floodplain meadow vegetation, which can otherwise create a lot of variation in the vegetation data that could conceal trends over time. If the site has no clear gradient, then a line between major watercourses is often useful, for example, from a river to a back drain. Transects can be identified and re-located using a string or a line of poles, or a GPS. The use of transects also makes it more straightforward to re-locate quadrats for subsequent monitoring than if they are randomly located.

Rare plants

Individual species can be targeted for survey if more information about their status and population changes are required. The survey method used will depend on the information required. The snakeshead fritillary is an example where a significant population has been surveyed annually by volunteers since 1999. In this case, monitoring year on year changes was the objective. Two-hundred 1 m x 1 m fixed, re-locatable quadrats were used to count the plants, and specific features, including height of plant, number of leaves and colour of flower, were recorded. The population trends shown as a result of these counts are valuable and findings are discussed more fully in Chapter 2 (pages 5 and 6).

NVC Surveys

Many floodplain meadows have already been surveyed and their communities mapped according to the National Vegetation Classification. However, if this is not the case, a survey to record and map NVC communities is recommended. *The National Vegetation Classification Users Handbook* (Rodwell 2006) provides full instructions; please refer to Chapter 8 for updated community descriptions. Expert help is often required with carrying out the survey and interpreting the results. Surveys should be repeated, as plant communities are not static and can be expected to change over time.

Sward height

In some cases it is necessary to measure the height of the vegetation, for example to see if agri-environment scheme criteria are being met. Estimates are often made by eye, or a few measurements taken with a ruler or more formally drop discs and sward sticks. If the height of the sward is key to management objectives, it is best to follow a set protocol. The drop-disc method is generally considered the most suitable method for large-scale monitoring of sward height on nature reserves and on land managed under agri-environmental schemes (Stewart *et al.* 2001).

Fixed-point photography

Fixed-point photography is a robust way of recording gross changes in floodplain meadows over time. While more detailed monitoring is also required, fixed-point photography is a cheap and effective way of illustrating change in a way that is highly accessible to non-experts. It can be carried out by anyone with access to a reasonable camera. Useful tips include:

- Record the location from which photographs are taken with as much accuracy as possible, and include the direction in which the photograph is taken. Use of fixed points (e.g. permanent features such as bridges) is best but should be supplemented with measured distances.
- Ensure that the lens specification stays the same (e.g. 35 mm).
- Take a previous set of photographs out into the field to ensure the location and direction is correct and to help with the degree of zoom used if the lens changes.
- Ensure the date and location number are added to the metadata of each photograph when it is downloaded.

What to do with vegetation data

Table 11.1 summarises how the results from different types of vegetation monitoring can be used. Data from fixed-point quadrats provide the opportunity for more detailed investigations into changes in species occurrence, for example by looking at species-richness and percentage frequency; these are discussed below.

Species-richness gives the number of species recorded, but not their relative abundance. To work out the average species-richness of a site, add together the number of species in each quadrat and divide by the number of quadrats. Doing this for each year will show any change in species-richness over time. For example, the data from Wheldrake Ings shown in Figure 11.3 show a gradual increase over time. Tests can be carried out to investigate the statistical significance of the results (some free resources to do this can be found online if software is not available).

How to record vegetation using quadrats

- Place a 1 m x 1 m quadrat centrally over quadrat marker cane, orientated parallel with the line.
- Record all species of vascular plant (grasses, sedges and herbs) and principal mosses (data sheets with pre-entered species names save time and make data-entry easier)[48].
- Assign a visual estimate of percentage cover to each species listed. The cover is the percentage of the ground area that the target species would shade if lit from above. A useful guide is that your hand placed flat in the quadrat is approximately 1% of the area.
- Check the total – the combined estimates may be over 100%, but on floodplain-meadow vegetation, totals rarely exceed 130%, so check the figure recorded for the dominant species if this is the case. Record the presence of species at <1% cover with a '+' on the data sheet.
- Always record actual percentage cover rather than using scales or measures of relative abundance such as DOMIN or DAFOR, as these are less sensitive and are less easy to integrate with other datasets.

A 1 m x 1 m quadrat being used in a floodplain meadow. The bamboo cane marks the middle of the quadrat. One-metre long canes are used to mark the sides, ensuring the quadrat is a neat square with right-angled corners. © Mike Dodd

The percentage frequency of individual species shows how many quadrats each species has been recorded from. Table 11.2 summarises how to calculate this using a data set of 71 quadrats as an example.

As with species-richness, percentage frequency can be compared over time to explore changes at a site. Figure 11.4 uses percentage frequency data to show how the extensive floods and resultant lack of hay cut in 2012 at North Meadow, Wiltshire had an impact on particular plant species in 2013. Recovery was seen to be starting in 2014, partly as a result of proactive management undertaken, in this case the removal of litter in the year that hay making was not possible and a prompt hay cut the next year.

Monitoring for birds

Monitoring for birds is of key importance in floodplain meadows as breeding waders or other ground-nesting birds may be present, including curlew, snipe, skylark and (a consequence of recent re-introductions) corncrake. This is particularly the case for larger sites. To protect chicks, it is

[48] See http://www.floodplainmeadows.org.uk/sites/www.floodplainmeadows.org.uk/files/files/d117796.pdf

How to set out transect lines

Transect and quadrat positions can be re-located relatively easily using Total Station surveying equipment[49] or a GPS with real-time correction giving an accuracy of <5 cm. If such equipment is not available, transects can be set out carefully using tape measures and a compass as follows:

Equipment:

- Sighting compass
- 50 m tape measure
- GPS if available (a GPS app. on a smart phone is usually adequate)
- Marker posts for the end of the transect or a means of marking existing features (e.g. paint or tape)
- 1.5 m long bamboo canes to mark out a line and 0.9 m long canes to mark sampling locations along it
- Metal plates to bury at known places along the line, if a metal detector is available

Procedure:

1. Start from a point that is easily re-located, or put in a robust marker post (fence posts are ideal).
2. From this marked point, choose an obvious feature on the other side of the site, or put in another marker, and note its compass bearing. Measure the location of marker posts from a fixed feature that is unlikely to move (e.g. a gate post) in case they go missing or are replaced.
3. If available, use a GPS to record the approximate grid reference of the marker posts (most GPS devices are accurate to about 5 m) to help future surveyors find them.
4. Note the bearing between the two posts and mark out a line using the long canes at regular intervals (this will require two people – one at the start point to keep the other on-line whilst placing the canes).
5. Once the line is defined with the long canes, use the tape measure and short canes to mark quadrat positions at given distances along the line. A spacing of at least 10 m is necessary if the locations are to be treated as independent samples; typical spacing ranges from 15 to 30 m depending on the size of the site.

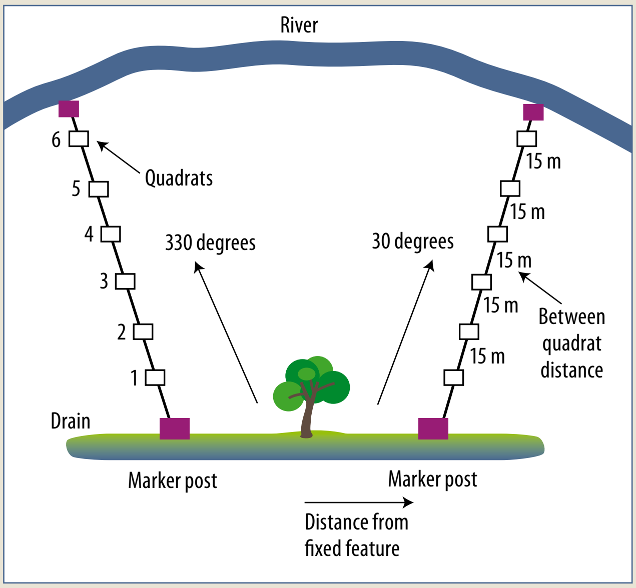


Figure 11.2 Schematic diagram of quadrats arranged along a transect line.

6. Record the position of the marker posts relative to other features, the orientation of the line and the distances between markers on a sketch map.
7. Photograph the end points and the transect line with the quadrat marker canes in place, and record where the photograph was taken from.

How many quadrats?

The number of quadrats required depends on the size and variability of the vegetation being monitored. Eight samples is the minimum number required to do any statistical assessment of change. Where there are correlations between two parameters (such as hydrology and management) then 12–16 is a more appropriate number. More detailed discussion on how to determine the number of quadrats can be found in Chapter 15 of *The Lowland Grassland Management Handbook*[50] (Crofts and Jefferson 1999).

[49] A theodolite with an electronic distance metre used to read slope distances from the instrument to a particular point.

[50] http://publications.naturalengland.org.uk/publication/35034

Figure 11.3 Data from fixed-point quadrats used to indicate changes in species-richness over time at Wheldrake Ings.

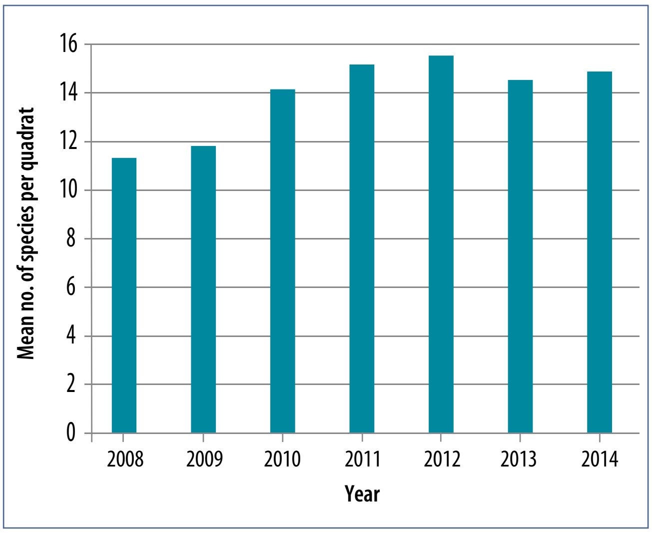


Table 11.1 How to use vegetation-monitoring results.

Monitoring technique	Shows
Fixed-point photography (same date each year if possible)	Visual record of changes over time
Sward height	Whether grazing regime is effective
Fixed-point quadrats	Vegetation change across the site including in relation to other factors such as changing hydrology
NVC	Change in community extent and cover across a site

Table 11.2 An example of calculating percentage frequency from quadrat data.

	Number of quadrats from which plant was recorded	% frequency (number of quadrat records/71 quadrat total) x 100
Rough meadow-grass	56 quadrats	(56/71 x 100) = 78.9%
Creeping-jenny	36 quadrats	(36/71 x 100) = 50.7%
Great burnet	25 quadrats	(25/71 x 100) = 35.2%

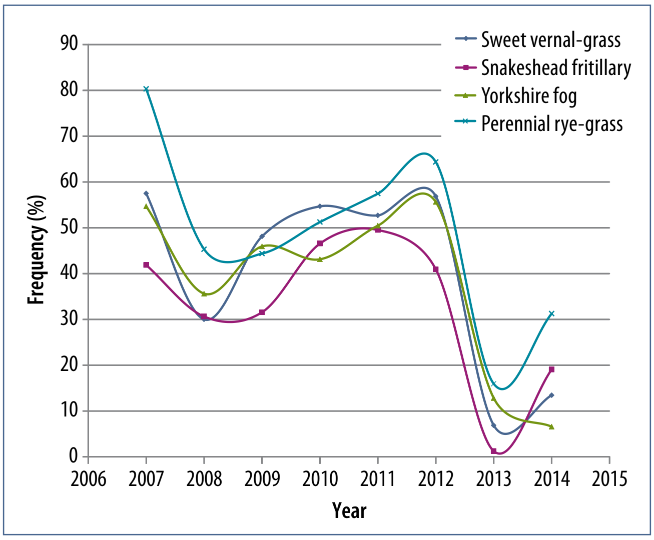


Figure 11.4 Percentage frequency data for four plant species over time at North Meadow, Wiltshire.

If there is a chance that waders such as lapwing (shown here) may be breeding on site, breeding wader surveys should be carried out to ensure management decisions are based on the most up-to-date information. © Mike Dodd

best to cut hay at a later date than is optimal for maintaining plant-species diversity (see Chapter 9). Therefore it is important to know if any of these species are present and breeding. If breeding is confirmed, hay should not be cut until the chicks are known to have fledged. Monitoring allows management to be adapted to the situation each year.

Monitoring guidance is given in *Bird Monitoring Methods: A Manual of Techniques for Key UK Species* (Gilbert, Gibbons and Evans 1998).

Monitoring protocols for other taxa

In many cases it may be desirable, although not essential, to set up monitoring programmes for other taxa. Links are given here for appropriate methodologies where these are readily available, and other sources of information.

- **Butterflies** – UK Butterfly Monitoring Scheme: www.ukbms.org/Methods.aspx
- **Dragonflies** – British Dragonfly Monitoring Scheme: http://www.british-dragonflies.org.uk/content/monitoring-dragonflies-and-damselflies-britain
- **Moths** – National Moth Recording Scheme: http://www.mothscount.org/text/27/national_moth_recording_scheme.html
- **Other breeding birds** – BTO/JNCC/RSPB Breeding Bird Survey methodology: www.bto.org/about-birds/birdtrends/2011/methods/breeding-bird-survey
- **Other invertebrates** – invertebrates tend to respond much quicker to change than plants, making them particularly suitable as an early warning system (Mortimer *et al.* 1998). Monitoring methods vary between groups, for example, pitfall traps are used for ground beetles and many spiders. It can be useful to identify to species level, depending on the reason for monitoring, but this requires appropriate ID skills, so expert advice would be needed. The Buglife website provides links to the relevant individual societies: https://www.buglife.org.uk/activities-for-you/wildlife-surveys
- **Small mammals** – the Mammal Society runs surveys and ongoing monitoring projects that feed into The National Mammal Atlas Project (NMAP): http://www.mammal.org.uk/surveys_and_monitoring

Hydrological monitoring

Once the water source and visible water movement have been determined (see Chapter 7), the key hydrological feature to measure is the depth to the water table. This need not be difficult or expensive, and can be done with readily available materials (see box – 'Installing a dipwell'). Dipwells can be used to monitor the elevation of the water table. They enable the water table to be measured routinely at fixed points within a meadow. Dipwells should be positioned along transects that generally run perpendicularly from watercourses to follow the local water-table gradient. A typical pattern for locating transects is given in Figure 11.5. If botanical transects have been set up, it is useful to place dipwells along the established transect line. Dipwells arranged at close spacing near to watercourses where the water-table gradient may be steep, and widely spaced in the centre of fields where the water table is likely to be flatter, can reveal further useful information. Hydrological and botanical data can then be linked to investigate the relationship between any changes in hydrology and plant communities.

Measuring water levels

Once installed, the dipwells should be left for one month to equilibrate with the water table. Thereafter, readings of the distance from the top of the pipe to the water surface in the well should be taken at fortnightly intervals using a 'plopper' or electronic 'buzzer' on the end of a measuring tape. These items can either be bought or constructed (see the Floodplain Meadow Partnership website[51]). Readings should be taken to the nearest centimetre and the date of each reading recorded.

Positioning dipwells in relation to quadrats

Where only a few quadrats are being recorded, i.e. along just one or two transects or where the relationship between the hydrological gradient and plant communities is being assessed, the dipwells should be on the same transect line as the quadrats (Figure 11.6 over).

Where more quadrats are being recorded, or a whole site assessment is required, or a particular area of a site is of

[51] http://www.floodplainmeadows.org.uk/sites/www.floodplainmeadows.org.uk/files/files/Buzzing%20stick.pdf

concern, a block of quadrats can be used. In these situations, dipwells are placed in or adjacent to blocks of quadrats and if possible also positioned along a hydrological gradient (see Figure 11.8). If the area being monitored is small, or experimental treatment blocks are being monitored, a block arrangement of quadrats may be more suitable (see Figure 11.9). Case Study 11.1 demonstrates a monitoring trial established using a plot-based system of quadrats to determine appropriate future management.

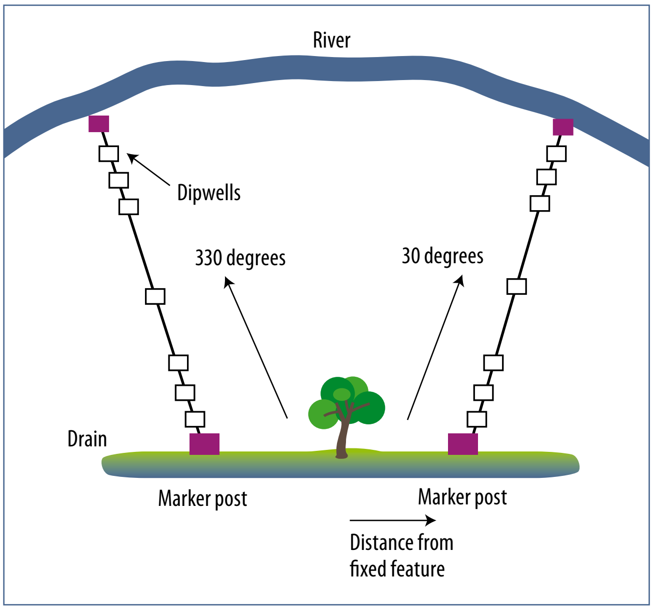


Figure 11.5 Generic location of dipwells across a hydrological gradient positioned in a line between the river and the back drain.

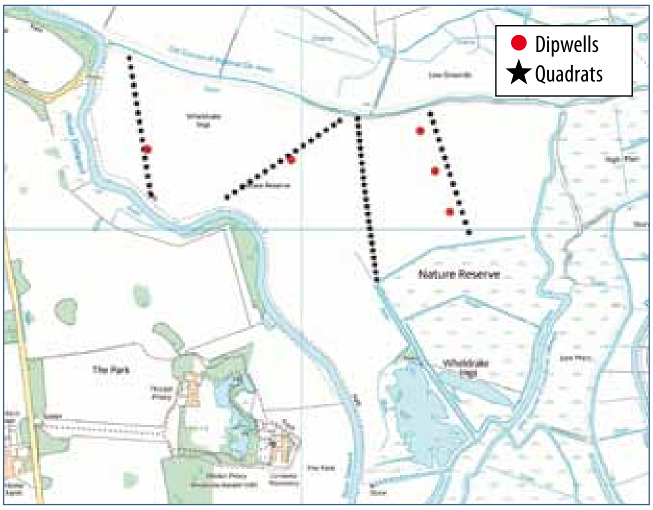


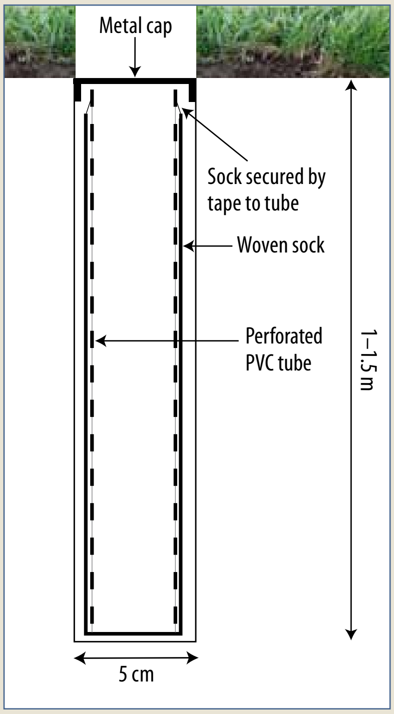
Figure 11.6 Quadrats are arranged along a hydrological gradient to monitor changes in the plant community following a change in the site's hydrological regime. Dipwells are positioned along some of the transects to help interpret the botanical changes seen. © Crown Copyright and Database Right [December 2015]. Ordnance Survey (Digimap Licence).

Installing a dipwell

This design has no impact on meadow management, machinery or livestock.

1. Buy 5 cm outside diameter PVC pipe (available from DIY stores as plumbing waste pipe).
2. For each well, cut a 1.0 m to 1.5 m length depending on the local soil profile (the tube should not penetrate a confined aquifer).
3. Perforate the tube with holes or slits of at least 5 mm diameter, along its entire length (except the top 100 mm, which should remain unperforated).
4. Cover the pipe with a sleeve of woven material to prevent silt entry. Specialist geotextile 'socking' can be purchased for the purpose or 'socks' can be stitched from tough woven nylon material (sheer ladies stockings are less suitable, as they tend to ladder during installation!).
5. The wells should be placed in hand-augered holes. In permeable soils, use a 5 cm diameter auger and place the pipe directly into the hole. In poorly structured (e.g. compacted) soils, auger a 10 cm diameter hole, place the 5 cm pipe within it and then backfill with a permeable material such as sharp sand. In this case, it will be necessary to seal the top of the hole with an impermeable clay such as sodium bentonite to avoid creating a preferential flow path for surface water. Bentonite clay can be purchased.
6. Install the pipe so that its top is approximately 3 cm below the surrounding ground level.
7. A metal plate (15 cm x 15 cm with downward pointing spikes to anchor it in the soil) should be placed over the pipe to prevent surface-water entry, to protect the pipe from damage by hooves and wheels and to assist in its re-location with a metal detector. This can be made using a local engineering workshop. Make a sketch map of the dipwell's location and record it with a standard GPS.
8. Survey the top of the pipe against a known benchmark so that absolute water levels may be calculated. The best method would be to use a theodolite or a differential GPS, both of which can be hired for a short period if someone with surveying experience is available. A more basic technique is to use a surveyor's level (dumpy level), which is cheaper to hire and can be used by non-experts after just a brief tutorial from the hire shop.

Figure 11.7 A schematic diagram of a soil-water dipwell in permeable soil. Note there should not be a gap between the sock, tube and soil.



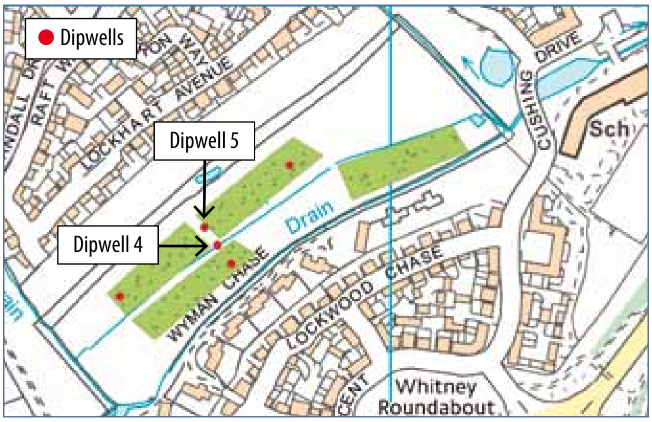


Figure 11.8 At Oxley Mead, Milton Keynes, 80 quadrats were situated in four blocks across the site. Dipwells were established in proximity to the blocks and positioned so the range of the hydrological gradient was also covered. © Crown Copyright and Database Right [December 2015]. Ordnance Survey (Digimap Licence).

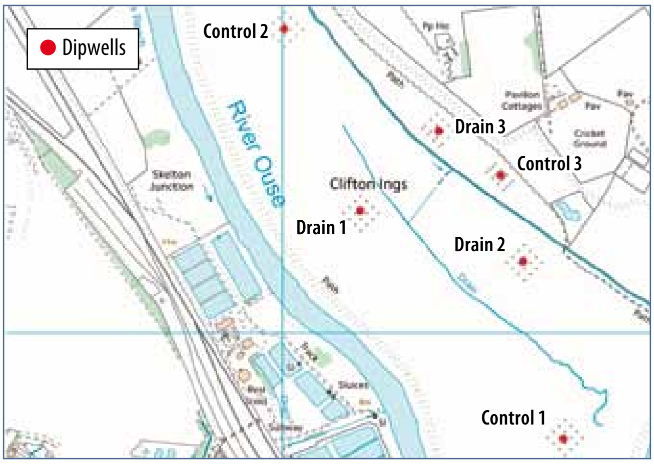


Figure 11.9 The location of six monitoring blocks (with 16 quadrats in each) at Clifton and Rawcliffe Ings SSSI (Yorkshire) together with positions of dipwells in red. The block arrangement was established to monitor the effects of different drainage works on the range of plant communities that might be affected. Drain indicates areas that are to have gutters reinstated whilst Control indicates areas with no alteration to their hydrological management. © Crown Copyright and Database Right [December 2015]. Ordnance Survey (Digimap Licence).

How to use hydrological data

The interpretation of hydrological data can be complex, but simple hydrographs can be used to illustrate differences in the hydrological profile across a site.

A hydrograph from a single dipwell shown in Figure 11.10 is presented as mean weekly water table depths relative to ground surface. Negative values indicate depth below the surface whilst positive values indicate flooding depth.

This hydrograph illustrates prolonged flooding in 2012–2013 with some flooding occurring in summer 2012, and water tables remaining high for a 12-month period. This contrasts to the relatively dry year in 2010–2011 when any flooding was brief and relatively shallow.

Dipwell 4 at Oxley Mead shown in Figure 11.11 is located in a ditch (shown in Figure 11.8) and so has shallower water-table depths than Dipwell 5. However, these dipwells rarely experience extensive flooding such as that shown in Figure 11.10.

Dipwell recordings can be interpreted in terms of number of weeks of wet and dry soil, and then plotted against an expected plant community's hydrological niche. This will demonstrate whether the hydrological regime at a site is suitable for the site objectives, and whether management changes have an impact on those plant communities. This is demonstrated in Chapter 10, Case Study 10.5: Seighford Moor, where increased ditch-water levels took the hydrological regime outside that supporting a species-rich floodplain meadow, triggering management actions to reduce ditch levels accordingly.

To understand this relationship between the soil-water levels, soil type and expected plant communities a simple Excel spreadsheet is available from the FMP website[52]. If site soil and hydrological data are entered, an expected plant community is predicted. Numbers of wet and dry weeks are also provided based on the data provided.

Figure 11.10 A hydrograph produced from a dipwell that experienced extensive flooding in 2012–2013.

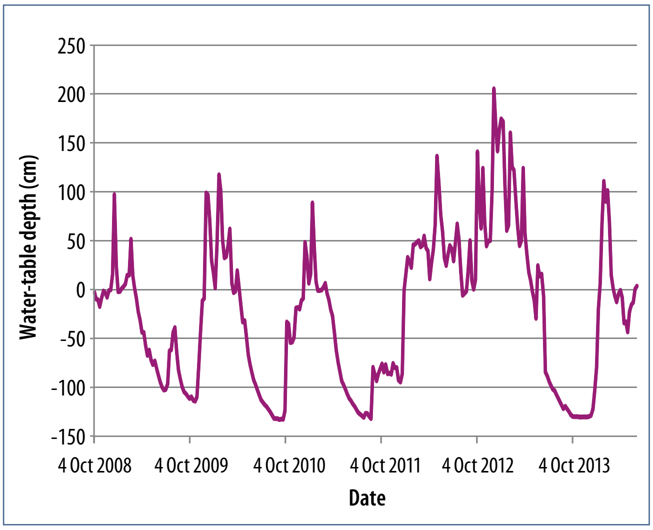
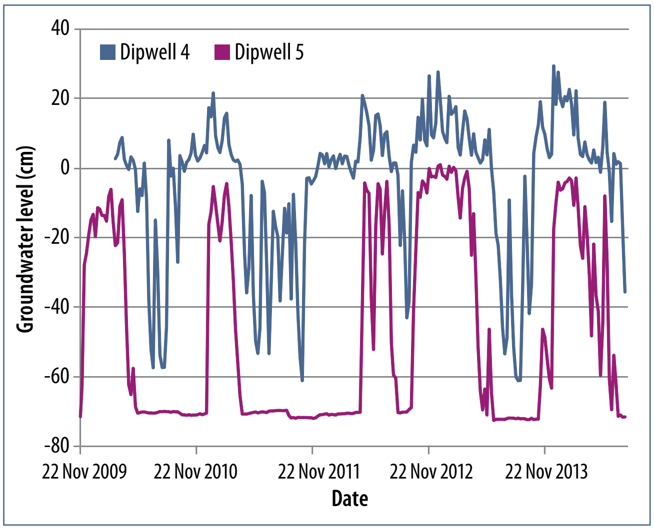


Figure 11.11 Hydrographs for two dipwells at Oxley Mead between January 2010 and July 2014.



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[52] http://www.floodplainmeadows.org.uk/about-meadows/restoration/evidence-base (scroll down the page to find the hydrotool download)

Monitoring calendar

Task	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1. Recruit surveyors (if not doing it oneself)	■	■										
2. Collect botanical data					■	■	■					
3. Collect dipwell data	■	■	■	■	■	■	■	■	■	■	■	■
4. Collect sediment samples	■	■	■									
5. Nutrient analysis of sediment			■	■	■							
6. Collect hay and soil samples					■	■						
7. Nutrient analysis of hay and soil							■	■	■	■	■	
8. Process and enter field data	■	■									■	■
9. Initial analysis and summary		■										

Note that monitoring times for other taxa are not included here as these vary according to group – see specific monitoring guidance for each group for more information.

Soil monitoring

Information on investigating profile, texture and structure of soils is given in Chapter 5. This can be done without specialist knowledge and with readily available equipment. However, to determine soil nutrients or characteristics relating to water availability and movement in soils (see Chapter 5), samples need to be analysed in a soil laboratory. It is important to ensure that the same analysis technique is used throughout the monitoring programme if samples are taken sequentially over time.

Sampling

Soil characteristics vary with depth, especially in a soil with clearly defined horizons. It is therefore very important to follow a set methodology that specifies the depth to be sampled. The most usual technique is to scrape back the litter layer exposing the top of the soil, and then extract the soil between zero and 10 cm below this. A soil corer (a bit like an extended apple corer) is useful here. The corer can be marked at 10 cm to ensure the correct depth is sampled. If a corer is not available, a trowel will do: push the trowel in vertically to 10 cm and twist to remove the soil sample. Some methods advocate 7.5 cm or 15 cm, rather than 10 cm, so be careful to ensure that the same depth is used throughout the monitoring programme.

Soil pH (see Chapter 6) measures the acidity of the soil, and can be determined using the same samples as those taken for nutrient determination. Again the pH can vary with depth and it is therefore important to sample at a known depth. Lime raises soil pH, which can get as high as pH 8.0; such a soil containing free calcium carbonate can be distinguished by dropping a soil sample into a small pot of vinegar. If fizzing is audible then it is likely that limestone is present.

How to use soil data

Table 5.1 in Chapter 5 elaborates on the different techniques for sampling soil and what these indicate.

Techniques to measure soil nutrients

Soil-nutrient analysis will generally be carried out in a specialist laboratory. The basic principles are outlined here.

- To measure the size of the total pools (see Chapter 5) of nutrients within the soil, it is necessary to attack the soil with heat and strong acid to release the nutrients from all their chemical forms and make them soluble. For total phosphorus (P), soil is ashed in a furnace at 450ºC and then dissolved in hydrochloric acid. For nitrogen (N), the Kjehldahl process can be used, which involves boiling the soil in acid.
- For the available nutrient pools, a more subtle approach is needed to ensure that only the pool of minerals that a plant root can access is assessed. For phosphorus availability, the most widely used chemical method for the type of soil found in floodplain meadows is the Olsen extraction method. This involves extracting P from the soil using a sodium bicarbonate solution. Other extractants are available, so it is necessary to double check which one has been used. For available N, a potassium chloride solution is usually used as the extractant.
- P concentrations in the soil are fairly stable, so taking samples gives a useful indication of phosphorus availability. Using the same approach for N is much more complex because the available pool is so dynamic and the results will be determined by the prevailing weather at the time of sampling and the stage of vegetation growth. To avoid this issue, soil cores can be taken for incubation in order to measure the rate of mineralisation, which is a more stable indicator of nitrogen supply to the vegetation. A relatively recent method for assessing nutrient availability is the use of an ion-exchange membrane. This consists of a small piece of plastic film covered in binding sites for negatively charged ions. It is buried in the soil for several weeks, during which time it simulates the action of plant roots by absorbing ions from the soil solution. At the end of the period the ions are washed off in the laboratory and measured.

Some other useful information that can be recorded

Hay sampling

To find out how much P is taken off in the hay crop, hay samples can be taken and analysed in a soils laboratory. This is useful if a nutrient budget is required or if the farmer has concerns about declining hay yield. Protocols are available on the Floodplain Meadow Partnership website[53].

Sediment sampling

The amount of P brought in by floods can be measured. This is desirable if there are concerns about eutrophication and wider catchment nutrient levels. Case Study 6.1 in Chapter 6 provides further information about methods involving the use of small pieces of astro turf.

Many thanks to additional contributor Justin Tilley.

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[53] http://www.floodplainmeadows.org.uk/about-research/research-your-site/monitoring

CASE STUDY 11.1
Fancott Woods and Meadows, Bedfordshire – using a monitored management trial to determine an appropriate change in site management

Fancott Woods and Meadows SSSI comprises two grassland fields and a wooded area. The southern field has ridge-and-furrow topography and a species-rich grassland intermediate between Burnet floodplain meadow (MG4) and Knapweed meadow (MG5) and has been managed as a hay meadow. The recent management of the northern field has been to turn cattle out in late June to graze the vegetation rather than cut it. Following wet summers in 2007–2009, meadowsweet has become dominant over parts of the site, suppressing less competitive species.

In 2008 a trial was established to:

- assess the effectiveness of a June hay cut on promoting species-richness in a previously grazed pasture;
- assess whether a timely hay cut is effective in suppressing meadowsweet, which has become dominant in some areas of the site.

The plant community composition was monitored in three blocks within the northern field from 2011–2015. Each block was divided into two plots and the plots randomly assigned to a cutting or non-cutting (grazing only) treatment (Figure 11.12). The 'cut' plots were mown by the end of June each year and the cut material removed from the plot. The 'uncut' plots received the previous management practice of grazing from the end of June with no material being cut and removed.

Results

Figure 11.13 shows that the cutting regime significantly reduces the cover of meadowsweet over a number of years compared to grazing only. Cutting as soon as the hay is ready (June) is a useful management tool to control the spread of meadowsweet, where it has become coarse and dominant.

Meadowsweet is a typical component of a floodplain-meadow sward, but it can become dominant if not cut regularly and promptly. If it is coarse and bulky, it does not make good hay and will reduce the species diversity of the meadow.
© Mike Dodd

Figure 11.12 Map of northern field of Fancott Woods and Meadows SSSI showing arrangement of cut vs grazed treatments and the corresponding allocation of five 1 m x 1 m quadrats per plot as indicated by a red star. © Crown Copyright and Database Right [December 2015]. Ordnance Survey (Digimap Licence).

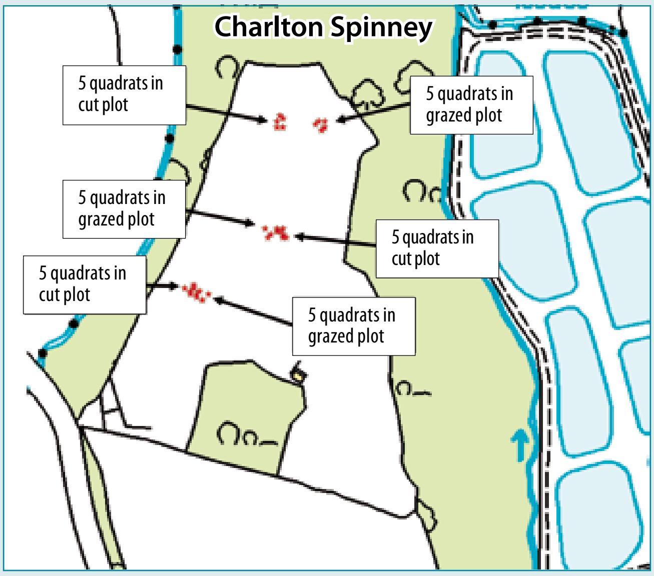
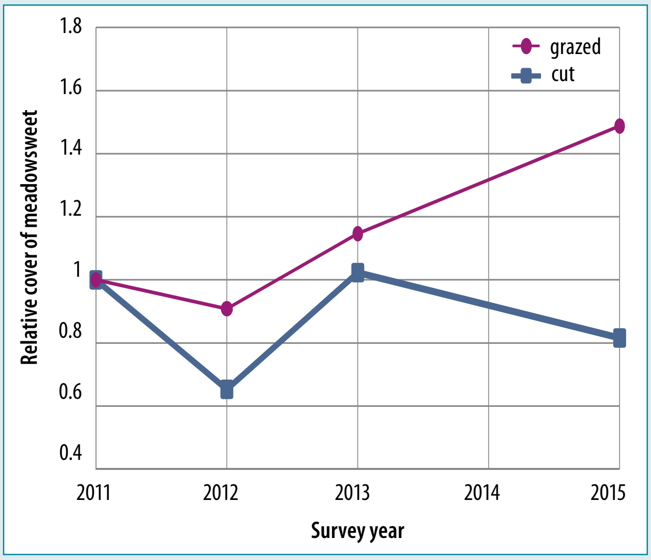


Figure 11.13 Results of Fancott Woods and Meadows management trial showing relative cover of meadowsweet in the different management regimes (cut annually in June) vs uncut (grazed only from late June onwards). No botanical recording was undertaken in 2014. © Crown Copyright and Database Right [December 2015]. Ordnance Survey (Digimap Licence).



Nomenclature

Plants

Adder's-tongue *Ophioglossum vulgatum*
Amphibious bistort *Persicaria amphibia*
Autumn hawkbit *Leontodon autumnalis*
Betony *Betonica officinalis*
Black medick *Medicago lupulina*
Blunt-flowered rush *Juncus subnodulosus*
Broad-leaved dock *Rumex obtusifolius*
Brown bent *Agrostis vinealis*
Brown sedge *Carex disticha*
Bulbous buttercup *Ranunculus bulbosus*
Burnet saxifrage *Pimpinella saxifraga*
Bush vetch *Vicia sepium*
Carnation sedge *Carex panicea*
Cleavers *Galium aparine*
Cock's-foot *Dactylis glomerata*
Common bent *Agrostis capillaris*
Common bird's-foot-trefoil *Lotus corniculatus*
Common comfrey *Symphytum officinale*
Common couch *Elytrigia repens*
Common knapweed *Centaurea nigra*
Common marsh-bedstraw *Galium palustre*
Common meadow-rue *Thalictrum flavum*
Common mouse-ear *Cerastium fontanum*
Common nettle *Urtica dioica*
Common ragwort *Senecio jacobaea*
Common reed *Phragmites australis*
Common sedge *Carex nigra*
Common sorrel *Rumex acetosa*
Common spike-rush *Eleocharis palustris*
Common valerian *Valeriana officinalis*
Common yellow-sedge *Carex demissa*
Cowslip *Primula veris*
Creeping bent *Agrostis stolonifera*
Creeping buttercup *Ranunculus repens*
Creeping cinquefoil *Potentilla reptans*
Creeping-jenny *Lysimachia nummularia*
Creeping thistle *Cirsium arvense*
Crested dog's-tail *Cynosurus cristatus*
Cuckooflower *Cardamine pratensis*
Curled dock *Rumex crispus*
Daisy *Bellis perennis*
Dandelion *Taraxacum* sect. *vulgaria*
Devil's-bit scabious *Succisa pratensis*
Downy-fruited sedge *Carex filiformis*
Downy oatgrass *Helichtrotrichon pubescens*
Dropwort *Filipendula vulgare*
Fairy flax *Linum catharticum*
False oat-grass *Arrhenatherum elatius*
Fen bedstraw *Galium uliginosum*
Field scabious *Knautia arvensis*
Field wood-rush *Luzula campestris*
Floating sweet-grass *Glyceria fluitans*
Glaucous sedge *Carex flacca*
Globeflower *Trollius europaeus*
Goat's-beard *Tragopogon pratensis*
Great burnet *Sanguisorba officinalis*
Greater bird's-foot-trefoil *Lotus pedunculatus*
Greater pond-sedge *Carex riparia*
Green-winged orchid *Orchis morio*
Hard rush *Juncus inflexus*
Heath-grass *Danthonia decumbens*
Hemp agrimony *Eupatorium cannabinum*
Himalayan balsam *Impatiens glandulifera*
Hogweed *Heracleum sphondylium*
Hybrid fescue *Festulolium loliaceum*
Jointed rush *Juncus articulatus*
Lady's bedstraw *Galium verum*
A lady's-mantle *Alchemilla xanthochlora*
Lady's-mantles *Alchemilla* agg.
Lesser hawkbit *Leontodon saxatilis*
Lesser pond-sedge *Carex acutiformis*
Lesser spearwort *Ranunculus flammula*
Lesser trefoil *Trifolium dubium*
Marsh arrowgrass *Trigolochin palustre*
Marsh foxtail *Alopecurus geniculatus*
Marsh hawk's-beard *Crepis paludosa*
Marsh horsetail *Equisetum palustre*
Marsh-marigold *Caltha palustris*
Marsh pennywort *Hydrocotyle vulgaris*
Marsh ragwort *Senecio aquaticus*
Marsh stitchwort *Stellaria palustris*
Marsh thistle *Cirsium palustre*
Meadow barley *Hordeum secalinum*
Meadow buttercup *Ranunculus acris*
Meadow brome *Bromus commutatus*
Meadow fescue *Schedonorus pratensis*
Meadow foxtail *Alopecurus pratensis*
Meadow thistle *Cirsium dissectum*
Meadow vetchling *Lathyrus pratensis*
Meadowsweet *Filipendula ulmaria*
Narrow-leaved water-dropwort *Oenanthe silaifolia*
Oil-seed rape *Brassica napus* ssp. *oleifera*
Oxeye daisy *Leucanthemum vulgare*
Pepper-saxifrage *Silaum silaus*
Perennial rye-grass *Lolium perenne*
Pignut *Conopodium majus*
Quaking-grass *Briza media*
Ragged-robin *Silene flos-cuculi*
Red clover *Trifolium pratense*
Red fescue *Festuca rubra*
Reed canary-grass *Phalaris arundinacea*
Reed sweet-grass *Glyceria maxima*
Ribwort plantain *Plantago lanceolata*
Rough hawkbit *Leontodon hispidus*
Rough meadow-grass *Poa trivialis*
Salad burnet *Sanguisorba minor*
Selfheal *Prunella vulgaris*
Sharp-flowered rush *Juncus acutiflorus*
Silverweed *Potentilla anserina*
Slender tufted-sedge *Carex acuta*
Smooth brome *Bromus racemosus*
Smooth hawk's beard *Crepis capillaris*
Snakeshead fritillary *Fritillaria meleagris*
Sneezewort *Achillea ptarmica*
Soft brome *Bromus hordeaceus*
Soft rush *Juncus effusus*
Spear thistle *Cirsium vulgare*
Sweet vernal-grass *Anthoxanthum odoratum*
Timothy *Phleum pratense*
Tubular water-dropwort *Oenanthe fistulosa*
Tufted forget-me-not *Myosotis laxa*
Tufted hair-grass *Deschampsia cespitosa*
Tufted vetch *Vicia cracca*
Water avens *Geum rivale*
Water mint *Mentha aquatica*
White clover *Trifolium repens*
Wild angelica *Angelica sylvestris*
Wood anemone *Anemone nemorosa*
Wood crane's-bill *Geranium sylvaticum*
Yarrow *Achillea millefolium*
Yellow oat-grass *Trisetum flavescens*
Yellow-rattle *Rhinanthus minor*
Yorkshire fog *Holcus lanatus*

Mammals

American mink *Neovison vison*
Barbastelle *Barbastella barbastellus*
Common shrew *Sorex araneus*
Daubenton's bat *Myotis daubentonii*
Field vole *Microtus agresti*
Harvest mouse *Micromys minutus*
Mole *Talpa europaea*
Noctule *Nyctalus noctula*
Otter *Lutra lutra*
Soprano pipistrelle *Pipistrellus pygmaeus*
Water shrew *Neomys fodiens*
Water vole *Arvicola amphibius*

Birds

Bewick's swan *Cygnus columbianus*
Black-tailed godwit *Limosa limosa*
Corncrake *Crex crex*
Curlew *Numenius arquata*
Fieldfare *Turdus pilaris*
Golden plover *Pluvialis apricaria*
Lapwing *Vanellus vanellus*
Redshank *Tringa totanus*
Redwing *Turdus iliacus*
Shoveler *Anas clypeata*
Skylark *Alauda arvensis*
Snipe *Gallinago gallinago*
Starling *Sturnus vulgaris*
Teal *Anas crecca*
Wigeon *Anas penelope*
Whimbrel *Numenius phoeopus*
Whooper swan *Cygnus cygnus*
Yellow wagtail *Motacilla flava*

Invertebrates

Chimney sweeper *Odezia atrata*
A click beetle *Ctenicera pectinicornis*
Common carder bee *Bombus (Thoracobombus) pascuorum*
Orange-tip *Anthocharis cardamines*
A sawfly *Abia sericea*
Six-spot burnet *Zygaena filipendulae*
Small copper *Lycaena phlaeas*
Tansy beetle *Chrysolina graminis*

European associations	
Great burnet-pepper-saxifrage association in the Netherlands and N. Germany	*Sanguisorbo-Silaetum*. Klapp ex. Hundt 1964
Snakeshead fritillary-meadow foxtail community of Dutch floodplains	*Fritillario-Alopecuretum pratensis*. Horsthuis et Schaminée 1993
Meadow foxtail-creeping buttercup-red clover meadow type from Poland	*Ranunculo-Alopecuretum*. Dierschke 1997 Ass. nov. Subcommunity *trifoletosum pratensi*
Snakeshead fritillary-meadow foxtail-marsh-marigold community	*Fritillario-Alopecuretum pratensis; Calthetosum*. Horsthuis et Schaminée 1993
Greater bird's-foot-trefoil sub-community of the Perennial rye-grass-crested dog's tail community in the Netherlands	*Lolio-Cynosuretum; Loletosum uliginosi*. Braun-blanquet et De Leeuw ex. Tüxen 1937
Meadow foxtail-narrow-leaved water-dropwort community of Croatia	*Oenantho silaifolae-Alopecuretum pratensis*. Stančić 2005 Ass. nov.
Meadow thistle-purple moor-grass community from the Netherlands	*Cirsio dissecti-Molinietum*. Sissingh et De Vries ex. Westhoff 1949
Jointed rush sub-community of the Buttercup spp-Marsh ragwort community in the Netherlands	*Ranunculo-Senecionetum juncetosum articulati*. Van Schaik ex. Schaminée et Weeda 1996 Ass. nov.
Rush-crested dog's-tail community of Sougnez (1957) from Belgium	*Junco acutiflori-Cynosuretum cristati*. Sougnez 1957
Snakeshead fritillary-meadow foxtail grassland, Crested dog's-tail sub-community from the Netherlands	*Fritillario-Alopecuretum pratensis; Cynosuretosum*. Horsthuis et Schaminée 1993

Ass. nov. = association nouveau: a relatively recent community or sub-community which has not previously been defined in the literature.

NVC code	Vernacular	Latin
W1	Sallow marsh woodland	*Salix cinerea-Galium palustre* woodland
W2	Sallow-birch fen carr	*Salix cinerea-Betula pubescens-Phragmites australis* woodland
W4	Hoary birch woodland	*Betula pubescens-Molinia caerulea* woodland
W6	Alder-nettle flood-plain woodland	*Alnus glutinosa-Urtica dioica* woodland
W7	Alder-ash flush woodland	*Alnus glutinosa-Fraxinus excelsior-Lysimachia nemorum* woodland
MG1	False oat-grass sward	*Arrhenatherum elatius* grassland
MG3	Northern hay-meadow	*Anthoxanthum odoratum-Geranium sylvaticum* grassland
MG4	Burnet floodplain meadow	*Alopecurus pratensis-Sanguisorba officinalis* grassland
MG4a	Cock's-foot sub-community	*Alopecurus pratensis-Sanguisorba officinalis* grassland *Dactylis glomerata* sub-community
MG4b	Typical sub-community	*Alopecurus pratensis-Sanguisorba officinalis* grassland Typical sub-community
MG4c	Yorkshire fog sub-community	*Alopecurus pratensis-Sanguisorba officinalis* grassland *Holcus lanatus* sub-community
MG4d	Creeping bent sub-community	*Alopecurus pratensis-Sanguisorba officinalis* grassland *Agrostis stolonifera* sub-community
MG5	Knapweed meadow	*Cynosurus cristatus-Centaurea nigra* grassland
MG6	Ryegrass pasture	*Lolium perenne-Cynosurus cristatus* grassland
MG6b	Sweet vernal-grass sub-community	*Lolium perenne-Cynosurus cristatus* grassland *Anthoxanthum odoratum* sub-community
MG6c	Yellow oat-grass sub-community	*Lolium perenne-Cynosurus cristatus* grassland *Trisetum flavescens* sub-community
MG6d	Meadowsweet sub-community	*Lolium perenne-Cynosurus cristatus* grassland *Filipendula ulmaria* sub-community
MG7	Ryegrass and other leys	*Lolium perenne* leys
MG7c	Perennial rye-grass-meadow foxtail-meadow fescue sub-community	*Lolium perenne-Alopecurus pratensis-Festuca pratensis* grassland
MG7d	Foxtail grassland sub-community	*Lolium perenne-Alopecurus pratensis* grassland
MG8	Kingcup-carnation sedge meadow	*Cynosurus cristatus-Carex panicea-Caltha palustris* meadow
MG8a	Burnet sub-community	*Cynosurus cristatus-Carex panicea-Caltha palustris* meadow *Sanguisorba officinalis* sub-community
MG8b	Typical sub-community	*Cynosurus cristatus-Carex panicea-Caltha palustris* meadow Typical sub-community
MG8c	Common sedge-lesser spearwort sub-community	*Cynosurus cristatus-Carex panicea-Caltha palustris* meadow *Carex nigra-Ranunculus flammula* sub-community
MG8d	Kingcup-daisy sub-community	*Cynosurus cristatus-Carex panicea-Caltha palustris* meadow *Caltha palustris-Bellis perennis* sub-community
MG9	Tufted hair-grass pasture	*Holcus lanatus-Deschampsia cespitosa* grassland
MG10	Soft rush-pasture	*Holcus lanatus-Juncus effusus* rush pasture
MG11	Silverweed flood-pasture	*Festuca rubra-Agrostis stolonifera-Potentilla anserina* grassland
MG13	Foxtail plash	*Agrostis stolonifera-Alopecurus geniculatus* grassland
MG14	Sedge lawn	*Carex nigra-Agrostis stolonifera-Senecio aquaticus* grassland
MG14a	Typical sub-community	*Carex nigra-Agrostis stolonifera-Senecio aquaticus* grassland Typical sub-community
MG14b	Sweet vernal-grass sub-community	*Carex nigra-Agrostis stolonifera-Senecio aquaticus* grassland *Anthoxanthum odoratum* sub-community
MG15p	Cuckooflower grassland (provisional)	*Alopecurus pratensis-Poa trivialis-Cardamine pratensis* grassland
MG15pa	Creeping bent sub-community	*Alopecurus pratensis-Poa trivialis-Cardamine pratensis* grassland *Agrostis stolonifera* sub-community
MG15pb	Ryegrass-meadow buttercup sub-community	*Alopecurus pratensis-Poa trivialis-Cardamine pratensis* grassland *Lolium perenne-Ranunculus acris* sub-community
M22	Blunt-flowered rush-pasture	*Juncus subnodulosus-Cirsium palustre* fen-meadow
M23	Sharp-flowered rush-pasture	*Juncus acutiflorus-Galium palustre* rush-pasture
M23b	Soft rush sub-community	*Juncus acutiflorus-Galium palustre* rush-pasture *Juncus effusus* sub-community
M27	Meadowsweet fen	*Filipendula ulmaria-Angelica sylvestris* mire
M28	Iris fen	*Iris pseudacorus-Filipendula ulmaria* mire
OV30	Bur-marigold mudsoak	*Bidens tripartita-Persicaria hydropiper* community
OV32	Keepsake mudsoak	*Myosotis scorpioides-Ranunculus sceleratus* community
S5	Sweet grass swamp	*Glyceria maxima* swamp
S19	Spike-rush swamp	*Eleocharis palustris* swamp
S28	Canary grass fen	*Phalaris arundinacea* tall-herb fen
A10	Amphibious bistort mat	*Persicaria amphibia* community

Glossary

adsorb – The process by which a substance accumulates on the surface of a solid to form a thin film

alluvium – Sediment that has been deposited by rivers during flood events

annual – A plant that completes its life cycle in one year

anoxia – A deficiency of oxygen

aquifer – A geological deposit (e.g. sand or chalk) that can both store and transmit water

available water capacity – The amount of water in a given soil that is available to plants; it is calculated as the difference between field capacity and permanent wilting point

biennial – A plant that completes its life cycle in two years

biomass/biomass stripping – Total amount of living matter in a given area/removal of the above-ground vegetation in a given area

bioprospecting – Process of discovering and commercialisation of new products based on biological resources

biosecurity – Security against the inadvertent, inappropriate, or intentional malicious or malevolent use of potentially dangerous biological agents or biotechnology

buzzing stick – Stick measuring about 2 m long with tape measure and buzzer which enables the depth of water in a dipwell to be measured

catch crop – A quick-growing crop planted between two regular crops grown in consecutive seasons, or between two rows of regular crops in the same season

cation – Positively charged ion such as Ca^{2+}, K^{+}, Mg^{2+}, Na^{+}, formed when a metal loses electrons

circumneutral – Lying around the mid-point of the pH scale.

constancy – Same as frequency. Five classes are used in the preparation of floristic tables

constancy table – A floristic table that is produced from field survey data for comparison against the published tables of the NVC

constant – A species that is present in >60% of samples of a vegetation unit (community or sub-community). Denoted as IV or V in the tables

customary acre – Strip or parcel of meadow allocated to a parishioner

DAFOR – A scale for estimating the frequency of a plant species within a site (Dominant, Abundant, Frequent, Occasional, Rare)

differential species – A species that is present in only one sub-community within a community

dipwell – A perforated tube sunk into the soil that enables the measurement of the depth to the water table

DOMIN – A scale for measuring the relative abundance of species based on percentage-cover categories

dormancy – Period of suspended growth and reduced metabolism

drowners – People employed to operate the hydraulic infrastructure on water meadows

embank – To protect or confine a waterway by a bank

eutrophication – Where pollution causes a soil or water body to become so rich in nutrients that some species grow so rapidly that other species become excluded

evapotranspiration – Water loss through both evaporation (from the soil) and transpiration (from the vegetation)

ferric – Containing iron in an oxidised state, designating an iron (III) compound

ferrous – Containing iron in a reduced state, designating an iron (II) compound

forage – Food for livestock, especially hay, straw or silage

frequency – The percentage of samples within which a species is recorded

genotype – A genetic make-up of a particular organism

GPS – Global Positioning System (GPS): a satellite-based navigation system providing location information

grips – Small drainage channels, also known as gutters or foot drains. These help remove surface water, but do not drain the soil profile itself to any degree

gutters – Small drainage channels

hydraulic conductivity – The ease with which water flows through a given soil

leys – Arable land put down to short-rotation grass crop, which is typically ploughed back in after a few years

manorial tennants – Tenants of the manor or local large estate

MATCH – A computer program to aid the assignment of vegetation data to the communities and sub-communities of the NVC

mesotrophic – Soils or waters that have moderate fertility (as opposed to high fertility – eutrophic; or low fertility – oligotrophic)

mineralisation – The release of nitrogen (or other minerals) from organic matter into soluble form

niche – The role or position an organism fills within an ecosystem

passage birds – Birds passing through on migration

passerine – An order of sparrow-like birds, characterised by the habit of perching in trees and bushes

penstock – A sluice for controlling water flow

perennial – A woody or herbaceous plant that continues its growth for at least three years

phenology – The study of recurring phenomena, such as plant-flowering times

phytosociology – The study of the composition, development, geographic distribution and environmental relationships of plant communities (Mueller-Dombois and Ellenberg 1974) based on their floristic composition

plant community – An assemblage of plant species that grow together in a particular place at the same time

power harrow – A machine that has multiple sets of vertical tines which are rotated vertically and till the soil horizontally. Soil layers are not turned over, so dormant weed seeds are not brought to the surface. A harrow is an implement used for breaking up and smoothing out the surface of the soil, to break up clods and create a seed bed

preferential species – A species in a floristic table that occurs at a higher frequency in one sub-community than in the community as a whole; and at a higher frequency than in any of the other sub-communities

quadrat – A sampling unit for vegetation; a plot of fixed size that is used for the recording of species lists. The resulting species list with the abundance of each is sometimes referred to as a *relevé*

rotovator – A machine that has rotating blades that will break up the soil, or work surface material into the soil

row up – The process of arranging cut hay into rows for drying

sample – The recording unit in the field; an area of fixed size used for the recording of species presence and abundance. Often referred to as the quadrat. In tables it is often referred to as a *relevé*

sequestration (carbon) The process of capture and long-term storage of atmospheric carbon dioxide

severalty – The tenure of property in one's own right, not jointly with others

silage – A crop harvested for fodder whilst still moist and allowed to partially ferment, effectively pickling the crop for prolonged storage

sill level – Height of the top of a sluice gate or penstock

sluice – A gate fitted to a channel to control the rate of flow of water

slurry – A mix of manure and water

spatial heterogeneity – Uneven distribution of environmental elements such as soil properties or species across an area

specific yield – The volume of water that can drain freely from a given volume of soil when surrounding water levels drop

stand – An area supporting vegetation that is homogeneous in its species composition. The building block of a vegetation map

structural heterogeneity – Uneven arrangement of structural elements across an area, such as a range of vegetation height

sub-community – Defined by species that are more frequent in that subdivision of the community than in the community as a whole

sulphide – A sulphur-based compound

terrace deposits – The layers of sand and gravel that underlie many floodplains, which were generally deposited by powerful floods that eroded upland areas as ice sheets retreated creating powerful meltwater floods each spring

tetrad – An area of 2 km by 2 km square used in mapping the distribution of species

tilling – The process of working the soil to provide a seed bed for crops

tithe map – A map of a parish or township prepared following the Tithe Commutation Act 1836, which allowed tithes to be paid in cash rather than goods. The map gives the names of owners and occupiers of land in the parish. A tithe was originally a payment in-kind (e.g. crops, wool, milk) made by parishioners for the support of the parish church and the clergy

transect – A line of quadrats/dipwells etc., used to monitor plant communities or hydrological gradients

turf stripping – The removal of the top layer of turf and soil from a field to reduce the soil fertility

variant – NVC sub-communities may occur along environmental or geographic gradients. This may result in a small but consistent departure from the published floristic table. Where such differences are well documented an extra, lower, tier of the classification is introduced – a variant of a sub-community

vascular plants – Plants that have specialised tissues for conducting water and nutrients around the plant. Includes all flowering plants, but not mosses

washland – Land that can be used for short-term floodwater storage

Appendix
Additional plant communities of floodplain meadows

This Appendix refers to some other plant communities found in floodplain meadows including species-poor grasslands, mires, swamps and ephemeral communities.

Species-poor grasslands

Tufted hair-grass is quite frequent in the species-poor, damper sub-communities of Burnet floodplain meadow (MG4) and also in the drier sub-community of Cuckooflower grassland (MG15p). However, together with Yorkshire fog, this species only achieves dominance and forms Tufted hair-grass pasture (MG9) on gleyed mineral soils with widely fluctuating water tables. These usually occur as relatively small stands within the floodplain-community matrix.

Soft rush-pasture (MG10) is also a community of gleyed mineral soils that remain wet all year. The vegetation most frequently develops from Ryegrass and other leys (MG7) or Ryegrass pastures (MG6) where re-seeding and drainage have not been fully successful. It is not part of the succession of semi-natural floodplain-meadow communities.

Foxtail grassland (MG7d): *Lolium perenne-Alopecurus pratensis* grassland

Like vegetation originally described as Perennial rye-grass-meadow foxtail-meadow fescue grassland (MG7c) (and see Cuckooflower grassland (MG15p)), this sub-community is most characteristic of moist and fertile alluvial soils in lowland floodplains where there is less frequent inundation and/or better drainage. In the absence of Burnet floodplain meadow (MG4), Foxtail grassland (MG7d) occupies the driest end of the hydrological gradient and is more closely allied to Ryegrass pasture (MG6). A sequence of the three vegetation types, Cuckooflower grassland (MG15p) – Foxtail grassland (MG7d) – Ryegrass pasture (MG6) in relation to soil moisture is well-demonstrated at West Sedgemoor (Wallace and Prosser 2007)[54].

Mires

Mire communities (see Rodwell 1991) tend to occur on the least fertile soils often where there is a local accumulation of humus (including around seepage lines and springs) and are tolerant of moderately waterlogged soils. Blunt-flowered rush-pasture (M22) is often found in association with Kingcup-carnation sedge meadow (MG8) from which it is not always easily separated, although it can be distinguished by the presence of frequent marsh thistle, marsh horsetail, greater bird's-foot-trefoil and water mint in addition to blunt-flowered rush. In general, stands occupy sites with higher soil moisture and pH than their Kingcup-carnation sedge meadow (MG8) counterparts, although they are found on similarly infertile sites.

Sharp-flowered rush-pasture (M23) can be found in stands of modest area on floodplain meadows, although in the lowlands it is more usually associated with fen basins or wet heaths (as on the Pembrokeshire Commons) and has a westerly distribution. On floodplain meadows, most stands are referable to the Soft rush sub-community (M23b) with Yorkshire fog, greater bird's-foot-trefoil, lesser spearwort and marsh thistle as characteristic associates. Other tall-herb fen species are present at low frequency and cover in stands that are variable in their species-richness, but generally less rich than Blunt-flowered rush-pasture (M22).

Meadowsweet fen (M27) develops where agricultural management has been much reduced in intensity or sometimes abandoned. Tall, bulky vegetation is dominated by meadowsweet with wild angelica, common valerian,

Soft rush pasture (MG10) at West Sedgemoor, Somerset.
© Hilary Wallace

Meadowsweet fen (M27) at West Hay, Somerset.
© Hilary Wallace

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[54] The 2006 NVC survey of West Sedgemoor did not specifically refer to Cuckooflower grassland (MG15p) as this community has only recently been provisionally identified as a separate community. However the gradation between the equivalent plant communities is clear.

Recently, invasion by both slender tufted-sedge and lesser pond-sedge has been noted across floodplains supporting Burnet floodplain meadow (MG4) and Kingcup-carnation sedge meadow (MG8), possibly due to higher spring water levels (Gowing and Wallace 2010). © Mike Dodd

common meadow-rue and soft rush with a lower storey normally including Yorkshire fog, water mint and common marsh-bedstraw.

Swamps

Swamps occupy the wettest areas of floodplain meadows and Canary grass fen (S28) (*Phalaris arundinacea* tall-herb fen) or Sweet grass swamp (S5) (Rodwell 1995) sometimes dominate where surface water is present throughout much of the summer. Stands are often poorly developed, although these grass reeds readily invade the hay sward from low-lying areas and ditches in exceptionally wet years. Spike-rush swamp (S19) forms part of the natural hydrological succession on floodplains and poorly developed stands are often found adjacent to the wettest areas of Kingcup-carnation sedge meadows (MG8) where conditions remain waterlogged throughout the summer.

Ephemeral Bur-marigold mudsoak (OV30) at Ashleworth Ham, Gloucestershire. © Hilary Wallace

Ephemeral communities

Extensive areas of bare ground often result from late-spring flooding, accompanied by high sediment deposition or eutrophication from winter wildfowl feeding. Colonisation of these areas depends on fertility levels, time of water drainage and the available seed bank. Five communities can occur but only two are frequent: Bur-marigold mudsoak (OV30) and Keepsake mudsoak (OV32) (Rodwell 2000). These ephemeral communities often only persist for one summer before being colonised by perennial grasses, leading to Foxtail plash (MG13) or Canary grass fen (S28). Again, the seeds of docks, spike rushes and other annuals that colonise these sites provide a rich food source for wintering ducks and waders – a notable example being on the Ouse Washes.

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Floodplain Meadows – Beauty and Utility

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