UK Forestry Standard **Practice Guide**

Creating and managing riparian woodland

Forestry Commission

Scottish Forestry
Coilltearachd na h-Alba

Cyfoeth Naturiol Cymru
Natural Resources Wales

FOREST SERVICE
An tSeirbhís Foraoisí

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Introduction

Riparian trees and woodlands occupy the land situated adjacent to waterbodies such as streams, rivers, ponds, lakes and reservoirs. They are critical to the natural functioning of freshwater ecosystems and form an important habitat in their own right (Figure 1). The interaction between running water, tree roots and fallen wood, as well as other forms of natural and semi-natural vegetation, creates the complex and dynamic aquatic and wetland habitat mosaic needed for characteristic plants and animals to thrive (Figure 2). Riparian trees and woodlands are also increasingly valued for providing a range of environmental benefits. These include stabilising stream banks and reducing channel erosion, controlling sediment and nutrient inputs from the adjacent land, regulating water temperature and helping to slow the flow of water to reduce flood risk further downstream (Figure 3).

Much of our riparian woodland has been lost due to clearance for development and agriculture, with what remains often highly fragmented or limited to occasional bankside trees. Although these remnants continue to provide valuable semi-natural riparian habitat, intensification of land management and the physical modification of river channels for flood protection have severely degraded habitat condition and function, leading to the loss of water-related ecosystem services.

Woodland creation is helping to replace some of the lost riparian woodland, while the restructuring of conifer plantations is improving riparian habitat within existing forests. Cultivation and inappropriate land drainage associated with conifer afforestation of the 20th century, as well as the excessive shade cast by the subsequent growth of planted conifer trees within the riparian zone, frequently resulted in unvegetated stream sides and more erodible stream banks. Restoration of the riparian zone and conversion to a variable cover of broadleaved trees and shrubs is recognised as having a key role to play in improving riparian and aquatic habitats and the ecological status of the UK's surface waterbodies.

Centuries of extensive woodland clearance has led to widespread loss of riparian woodland and impoverished riparian habitat.

There is now an urgent need to further restore and expand riparian woodland and habitat within existing forested areas and as part of new woodland creation schemes. The goal is to create a fully functioning dynamic linear network of riparian vegetation of variable tree cover to help protect freshwater and wetland habitats while delivering multiple benefits for society. Doing so will contribute to efforts in adapting to climate change and, to some extent, help to address the biodiversity crisis.

Figure 1 Riparian woodlands occur on seasonally wet soils, usually with alder, birch and willow as the predominant tree species, but sometimes with ash, oak and Scots pine on drier areas.

Figure 2 Positive management of the riparian zone can protect and enhance the aquatic environment. It should include open and lightly wooded habitat of native tree and shrub species or other ecologically appropriate broadleaved trees.

Figure 3 Riparian woodland planting was included in the River Ribble catchment restoration scheme in Yorkshire to improve aquatic habitat, reduce diffuse pollution, mitigate the effects of climate change and reduce flooding.

The UK Forestry Standard (UKFS) defines the agreed approach to sustainable forest management across all four administrations of the UK. The UKFS includes a set of Requirements and Guidelines on conserving biodiversity and protecting the water environment, many of which apply directly to the riparian zone. An important Good Practice Requirement is the creation of buffer areas along all perennial watercourses and the shoreline of waterbodies within woodlands and forests, to establish and maintain a mix of shaded and lightly shaded riparian habitat. Riparian buffer areas should be included in forest design plans and managed to enhance freshwater and wetland habitats, as well as to reduce the potentially adverse effects of land-management activities on the adjacent land.

Aim and scope

The purpose of this Practice Guide is to assist forest and woodland owners, planners and managers, by giving more detailed information on planning, designing and managing riparian woodland to comply with UKFS Requirements and Guidelines. This Guide provides an overview of the benefits of riparian woodland and sets out good practice aimed at mitigating any potentially adverse effects on the freshwater ecosystem. Guidance is provided on planning new riparian woodland, restoring riparian zones within existing conifer forests, and on the management of riparian trees and woodland. It also provides specific sections relating to the management of deadwood, protected species and the control of invasive non-native species in riparian buffer areas. Emphasis is placed on achieving a variable level of riparian woodland cover that is appropriate to local conditions, sensitivities and objectives. The Guide is based on ecological principles and is informed by research results and practical experience.

The Practice Guide does not cover the management of open wetland habitats of high conservation status, such as blanket bog, upland flushes, fens and swamps, which are the subject of UKFS Practice Guide 24, *Managing open habitats in upland forests*. Guidance on forest and woodland-based natural flood management, including the contribution of floodplain woodland and leaky woody dams, is provided by UKFS Practice Guide 27, *Designing and managing forests and woodlands to reduce flood risk*.

Benefits of riparian woodland

The riparian zone is naturally dynamic and ecologically rich because of the spatial and temporal variability in environmental conditions associated with the water's edge (Box 1). Appropriately sited riparian woodland provides multiple environmental benefits, including enhancing ecosystem diversity and forming an important habitat for priority species; supplying leaf litter, deadwood and a source of energy; providing shade and regulating water temperature; slowing water flows; reducing diffuse pollution from the adjacent land; protecting riverbanks; and for carbon storage. Riparian woodland can also enhance the appearance of water bodies, adding to the amenity value of the landscape.

Enhancing ecosystem diversity

Riparian woodland can enhance both structural and hydrological diversity within riparian and aquatic zones, potentially creating an intricate mosaic of multilayered habitats over a relatively small area (Figure 4). The riparian zone, whether adjacent to river and stream channels or lakes and ponds, can be a place where wetland plant and animal species thrive, and which provides breeding, shelter and feeding opportunities for freshwater species that spend time out of the water. Riparian trees have a particularly important role: their canopies provide shade and leaf litter, while their root systems and deadwood provide shelter, influence water flows and affect sediment erosion and deposition patterns, generating habitat complexity.

While few rare plant species are dependent on riparian woodland, it can support a large number of characteristic species; the high humidity and shade particularly favour the growth of mosses, lichens and ferns. The 'Atlantic rain forest' bryophytes, lichens and ferns are some of the rarest species and include a number that are only found in certain parts of the UK, especially in Wales and western Scotland. Bankside trees are particularly important, but the benefits to habitat creation are greatest where a variable tree cover extends across the riparian zone to create a fully functioning and ecologically rich wet woodland system (Figure 5).

Figure 4 Riparian woodlands can form wet woodland, which is a rare, priority habitat in the UK. The ground vegetation is very varied and can include large grasses, sedges, rushes, herbs and mosses.

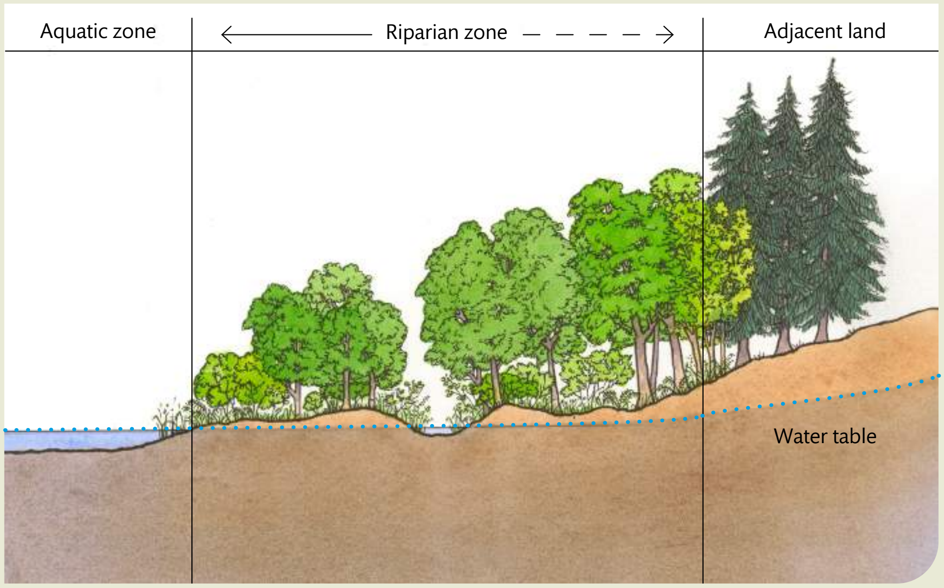
Figure 5 The riparian canopy should be variable along the stream corridor, including open areas and pockets of deeper shade, to provide a range of different conditions and microhabitats, as shown on this riverbank in Glenmore Forest Park, Scottish Highlands.

Trees immediately next to and interacting with open freshwater habitat can play a significant role in habitat functioning. Deadwood and tree roots provide habitat for mosses, liverworts, algae, invertebrates and fish. Along with leaf litter they also provide a food source. Tree root systems and fallen woody material in rivers and streams are also instrumental in the natural shaping of diverse and dynamic habitat mosaics, interacting with water flow to generate complex erosion and sediment deposition patterns and associated variation in water depth, speed and direction. Conversely, a lack of mature trees and their stabilising tree root systems (which extend underneath the river and stream channels) can cause the channel to cut downwards, which increases channel depth, reduces wetland character in the riparian zone and destabilises banks. The more diverse the habitat, the greater the number of species that can live there and the more resilient the ecosystem is to high flows and extreme temperatures.

Box 1 The riparian zone

The riparian zone occupies the land adjacent to the aquatic zone and is influenced by it. It encompasses the transition between aquatic and terrestrial habitats, in which there is typically a gradient in ecology, hydrology and geomorphic conditions. The natural width of the riparian zone varies along the bank of the watercourse or lake shore, depending on valley form, slope, geology, soil and size of the water body. Along smaller watercourses, it typically comprises the adjacent narrow floodplain extending from the stream bank to the break of slope, although it can also encompass steep valley sides affected by high humidity and water spray, such as within gorges. On larger rivers it merges into the wider floodplain, although is often constrained by flood embankments and the built environment. It does not include the aquatic zone, which is the area permanently or frequently under water forming seasonal aquatic features such as wetlands, pools, lakes, streams, rivers, estuaries and coastal waters. The riparian zone can extend along artificial open ditches and drains where it is typically very narrow in width.

The establishment and maintenance of semi-natural vegetation around water bodies has multiple purposes, forming an integral part of freshwater habitats, with an essential ecological role in supporting characteristic species and ecosystem functioning.



Providing and connecting habitats for priority species

Riparian woodland can form wet woodland priority habitat, as well as being an integral part of priority river and standing water habitats. It also frequently occurs in a mosaic with other key woodland and open wetland habitats, requiring design and management to consider the needs of both, including that of dependent protected and priority species. It is important to check for the presence of these and adjust objectives accordingly. By linking woodland habitats, riparian woodland can also play an important role in supporting the movement of priority species across the wider landscape. Up-to-date guidance on managing forests and woodlands that do, or may, contain protected species is available online from the relevant country authority website (see Further reading and useful sources of information). Woodland managers should familiarise themselves with good practice requirements before commencing work and must satisfy themselves that any plans consider all relevant legislation and do not contravene legal requirements. Specific guidance on the management of riparian woodland for key species is provided on pages 29-35.

As well as aiding the migration of protected and priority species between woodland habitats, riparian woodland can increase woodland diversity across landscapes by enhancing connectivity, either by directly connecting smaller woodlands and trees outside woodland, or acting as 'stepping stones', particularly in more intensively used and open landscapes.

Supplying a food source for freshwater life

The riparian woodland canopy controls the levels of sunlight reaching a watercourse, which limits aquatic photosynthesis and the rate of primary production. Leaf litter falling into the water therefore forms the foundation and principal energy source of the river's food chain, especially within headwater streams and standing waters. Riparian woodland supports an instream ecology dominated by the seasonal input of leaf litter that is subsequently decomposed by microorganisms and specialist invertebrates. In-stream productivity is enhanced by a diversity of riparian tree species, as different species drop their leaves at different times and their leaves decay at different rates. More palatable leaves such as those of bird cherry take a few weeks to break down, whereas oak leaves take several months.

> Invertebrates falling into the water from the leaves and branches of trees can form up to 90% of the diet for a number of salmonid fish, such as the brown trout.

Providing shade

Freshwater ecology is directly influenced by water temperature, which controls river fauna metabolism and dissolved oxygen concentrations. Canopy shade has an increasingly important role to play in limiting the rise in water temperature due to climate warming, with summer maxima already exceeding the thermal limits for cold water-adapted species, such as salmonids. Riparian shade also reduces algal and weed growth that can choke watercourses and blanket fish-spawning gravel redds. The effectiveness of shade varies with the size/width of the water body, as well as by the orientation of a watercourse and the nature of local topography.

Diversifying water flows

The physical presence of trees, bankside roots and inputs of deadwood locally deflects and attenuates water flow. This enhances the formation of dynamic pool and riffle sequences, which form a range of habitats of varying water depth and speed that enrich fish and spawning habitat, as well as providing refuges for aquatic life during periods of high flows. Leaky woody dams and associated pools also help to retain twigs, branches and leaf litter, enhancing the quantity of food to support aquatic ecology. They also promote out-of-bank flows (Figure 6), encouraging siltation on the floodplain, re-wetting the riparian zone, sustaining dry weather flows and potentially reducing downstream flood risk.

Reducing diffuse pollution

Diffuse pollution is the release of pollutants from dispersed land-use activities across a catchment, and can have a significant detrimental impact on the water environment.

While the primary focus should be on minimising sources of diffuse pollution by good soil and land management, the riparian zone can play an important role in protecting water quality and reducing impacts on the aquatic environment. Riparian vegetation, particularly trees, can be very effective at intercepting and removing pollutants from the atmosphere and in run-off from the adjacent land. The effectiveness of pollutant removal depends on a wide range of local factors, including the design (especially width) and management of riparian woodland, the type of pollutant and the pathway of pollutant movement. Impacts are potentially greatest for sediment, nutrients such as nitrogen and phosphorus, as well as pesticides. Excessive delivery of pollutants can damage and degrade riparian habitats, including their scope to intercept and remove pollutants, leading to pollutant saturation. Thus, it remains critical for land-management practices to tackle pollution delivery at source to avoid overloading the riparian buffer area.

Climate change predictions suggest that the risk of diffuse pollution is likely to increase in the future due to wetter winters, more intense summer storms and more frequent droughts. These changes will affect pollutant loads to water, pathways of movement and the ability of watercourses to cope with pollutant inputs.

Figure 6 Riparian woodland provides a natural supply of woody material to watercourses, creating a dynamic network of leaky woody dams that can be effective at holding back flood flows, such as in this example from the New Forest in Hampshire.

Sediment

Soil disturbance caused by cultivation, drainage and other land-management activities can increase soil erosion and the movement of sediment to watercourses, resulting in siltation, reduced water clarity and damage to freshwater ecology. Sediment loss is dependent on land use, soil type, slope and prevailing weather, so the pressure varies across a catchment and throughout the year. Riparian woodland protects the soil and enhances soil infiltration, reducing direct surface run-off. Surface rooting, tree stumps, deadwood and ground vegetation slow run-off and aid the settlement and capture of suspended sediment within the riparian zone and on floodplains, reducing sediment delivery to watercourses, where it causes most harm. Sediment trapping is most effective for coarser, sandy sediment, which is largely captured by the first few metres of the buffer area. Removal of fine sediment such as silts and clays requires a much wider buffer area or surface run-off to infiltrate the soil.

Nutrients

Nutrients are essential for freshwater life, but in excess they can cause detrimental changes and reduce water quality through eutrophication. This can lead to reduced biodiversity and, in the case of standing waters, toxic algal blooms and anoxia. The main nutrients of concern are nitrogen and phosphorus.

Nitrogen is mainly transported to watercourses in a dissolved form (nitrate or ammonium) from agricultural activities. Peak concentrations occur after fertiliser and manure/slurry applications or after crops are harvested. Nitrate is removed from the soil by growing trees and also by a process called denitrification, during which dissolved nitrate is converted by soil bacteria to gaseous nitrous oxide and nitrogen, which are then released into the atmosphere. Denitrification is most efficient in warmer temperatures on wet soils where there are decomposing plant residues. Nitrogen saturation and enhanced leaching of nitrate to water can occur if riparian woodland is overloaded by nitrogen inputs from the adjacent land. This can potentially be managed by tree harvesting to remove the accumulated nitrogen in biomass followed by replanting. Another potential issue is the ability of alder to fix nitrogen and thereby increase the leaching of nitrate to water.

Phosphorus can be transported to watercourses in a dissolved form (phosphate) or bound to soil particles in surface or near-surface run-off. The latter is particularly the case in run-off from clay-rich soils with high levels of aluminium and iron (e.g. paleo-argillic and gley podzols). Adsorption of phosphorus is limited in peaty soils and in heavily fertilised soils with an excess of phosphorus. Peak concentrations tend to occur during the winter when ground vegetation cover is reduced and biologically inactive. Wider areas of riparian woodland are needed to remove phosphorus in solution, but the primary removal mechanism is by the trapping and deposition of sediment, as described above. As with nitrogen, tree harvesting within riparian buffer areas may be required to prevent phosphorus saturation and remobilisation to water.

While as much as 80% of the annual uptake of nitrogen can be returned to the soil in the form of fallen leaves and fine root decay, this tends to be incorporated into soil organic matter and only slowly released to water.

Pesticides

Pesticide pollution poses a serious threat to drinking water and is potentially lethal to the freshwater environment. Water can be contaminated by pesticides via deposition from the air, in solution or adsorbed to eroded soil particles. Very low concentrations in water are sufficient to degrade water quality and cause serious damage to freshwater life. Riparian woodland can reduce water contamination by providing a physical barrier to pesticide spray drift, by removing sediment in run-off and by promoting pesticide adsorption in woodland soils.

Microbial pathogens

The contamination of surface run-off by microbial pathogens from livestock is a serious threat to drinking and bathing waters. Information is lacking to assess the effectiveness of riparian woodland for removing pathogens in run-off, but some reduction can be expected, especially where run-off is delayed and able to infiltrate the soil. A significant reduction in contamination can be achieved by fencing to exclude livestock from the buffer area and aquatic zone.

Riverbank protection

Riparian trees play an important role in the protection of riverbanks and adjacent side slopes. Tree roots deflect flows and help to strengthen and stabilise riverbanks, reducing the risk of bank collapse, channel erosion and thereby channels becoming too deep and isolated from the riparian zone. Tree cover and associated rooting also help to increase slope stability by reducing soil disturbance, improving soil structure and drainage, and by binding weak soils, reducing sediment load and deposition.

Carbon storage

High water tables and anoxic soil conditions in the riparian zone are conducive to carbon retention and long-term storage. Inputs of deadwood and leaf litter from riparian woodland enhance soil carbon stocks, as does the capture and deposition of silt and organic matter in run-off from the adjacent land and during flood flows. Leaky woody dams and associated accumulations of woody material, leaf litter and dissolved organic carbon also represent a significant, albeit temporary, carbon store within watercourses. The greenhouse gas benefit from increased carbon storage within the riparian zone can be offset by higher nitrous oxide and methane production, although the overall balance remains uncertain.

Adverse effects of riparian woodland

While riparian woodland is generally beneficial for the water environment, there are some exceptions. Most of these relate to the poor design, location or management of the riparian woodland and can be addressed by adopting good practice. For example, the past practice of planting conifers in the riparian zone, which was halted in the 1980s (Figure 7), has created legacy issues that continue to require corrective action, including the need to disconnect forest drains.

Conifers and some broadleaves can cast dense shade on stream sides, which reduces plant growth and leads to a lack of ground vegetation and bare soil that becomes vulnerable to excessive erosion. This reduces the diversity of riparian habitat and supporting species, and can result in wider, shallower stream channels, with increased sedimentation. Excessive shade also lowers the water temperature, which can limit the growth of fish in cooler areas, while conifer needles form a poor food source for aquatic invertebrates. Although many productive conifers have since been cleared back from stream sides, others have yet to be felled, and sizeable areas of cleared ground have still to be restored to riparian broadleaved woodland. Dense shading can also be an issue for some riparian broadleaved trees unless managed appropriately.

Poorly designed and managed riparian woodland can adversely affect open habitats. In particular, the encroachment of woody vegetation, including regenerating conifer trees, can reduce habitat quality by shading out and potentially drying important flush communities. Similar issues can affect the margins of lakes and ponds, as well as large inputs of leaf litter smothering bed sediments and reducing plant growth and development. Riparian woodland can also complicate the control of invasive, non-native species that threaten open habitats.

Without proper consideration, riparian woodland creation in areas that were previously open can also impact the habitats of protected and priority species that depend on open banksides, such as wading birds, water voles, invertebrates and amphibians (e.g. great crested newts).

Figure 7 Conifers should be removed from the riparian zone because heavy shade restricts the growth of ground vegetation and leaves stream banks vulnerable to windblow and erosion.

Appropriate baseline species surveys will inform decisions on where and how to approach woodland creation in such riparian areas.

Other issues relate to the location of the riparian woodland. The backing up of floodwaters because of the attenuation of in-stream flows is a potentially valuable contribution to natural flood management, but in the wrong place can increase the flooding of nearby upstream properties. The accompanying raised soil water tables and deflection of flows may also cause problems for adjacent landowners, while the washout of deadwood may increase downstream flooding by blocking downstream culverts and bridges. These issues can be effectively managed by careful siting and design of riparian woodland (see UKFS Practice Guide 27, *Designing and managing forests and woodlands to reduce flood risk*).

In acid-vulnerable catchments, alder can contribute to soil and water acidification because of nitrogen fixation and nitrate release (see UKFS Practice Guide 23, *Managing forests in acid sensitive water catchments and country guidance where available)*. In other areas that are vulnerable to periods of low flows and water shortages, some riparian woodland species such as willow and poplar may exacerbate these problems because of their potentially high water use, depending on the extent to which this is compensated by increased water retention due to slowing the flow.

Riparian zones have formed important corridors through the landscape for people over thousands of years and often contain many heritage features. The same applies to adjacent rivers and lakes. New planting, as well as tree growth, may have adverse impacts on these heritage features and therefore requires careful consideration when riparian woodlands are being created or managed.

In some circumstances, the benefit of riparian woodland for protecting riverbanks and reducing channel erosion can be a disadvantage by reducing channel mobility. Insufficient shingle bank production can threaten some rare and declining shingle specialist species such as the little ringed plover and the five-spot ladybird.

Planning new riparian woodland

The decision to create new riparian woodland can be driven by various objectives, from a desire to create or restore riparian woodland habitat for biodiversity gain or natural processes, to protecting and enhancing the freshwater environment by attenuating pressures such as diffuse water pollution, flooding or the effects of climate warming. Much will depend on landowner interests and funding, as well as on the nature and condition of existing riparian habitat; the presence of priority habitats and priority or protected species; the status of the water environment; and local environmental pressures. The objective(s) of the planting could have a strong influence on riparian woodland design and management, such as to enhance effectiveness for reducing water pressures.

The riparian zone provides an opportunity to create long-term permanent woodland structure of linked habitat, consisting predominantly of native broadleaved woodland canopy, shrubs and open space.

Areas of existing priority habitat, including wet woodland, should be considered when planning new riparian woodland. Open glades should be designed around patches of wetland habitat such as spring flush plant communities, while larger areas of open ground should protect fens, swamps and other groundwater-dependent terrestrial wetlands. The needs of individual priority and protected species may differ and must be balanced.

Early consultation with appropriate organisations will guide decision-making, informed by country policies and area designations and sensitivities. Long-term planning and co-ordinated action will be required to achieve change at a catchment or landscape level, including the creation of a wider riparian habitat network or to reduce flood risk as part of an integrated natural flood-management scheme. Advice and permissions may need to be sought from the appropriate regulatory authorities.

Site selection

By definition, riparian woodland is limited to the riparian zone. This is determined by the nature of the aquatic zone, which is largely dictated by local topography and geology, as well as by climate (Box 1). Planting anywhere within the riparian zone of a watercourse or standing water has the potential to create riparian woodland. Site suitability will vary depending on the status and quality of open habitats, landscape designations and environmental factors, including altitude, exposure, depth of flooding and adjacent land use. Addressing environmental pressures requires more careful targeting, both in terms of location and scale of planting. The locations most likely to benefit from riparian woodland are:

- degraded, sparse, fragmented or relic areas of existing riparian woodland, especially where there is an opportunity to connect with adjacent woodland to create a forest habitat network;
- areas that are important for protected and priority species, such as salmon and freshwater pearl mussel, with a lack of riparian woodland and shade (see Keeping Rivers Cool guidance);
- where the freshwater environment is impacted by diffuse pollution via surface or near-surface run-off, especially where riparian zones are not bypassed by field drains, unless these can be disrupted (Figure 8);
- along physically degraded or straightened sections of watercourse as part of a river-restoration scheme;
- upstream of communities or assets at risk of flooding, especially along natural watercourses that flood regularly or could be encouraged to flood seasonally without significant risk to neighbours or fallen trees blocking downstream bridges and culverts;

! Riparian owners must abide by regulations and obtain the necessary authorisation from the relevant flooding authority prior to undertaking any activities in or adjacent to watercourses that could affect water flows or channel structure. The definition of 'in or adjacent to watercourses' is dependent on legislation and regional byelaws.

Figure 8 Native riparian woodland planting along a length of the River Hodder in Lancashire, England, to restore riparian woodland habitat, reduce diffuse pollution from the adjacent land and help alleviate downstream flooding.

- along watercourses with adjacent unstable steep slopes or banksides, provided that fallen trees do not pose a significant downstream flood risk.

Locations where planting riparian woodland is unlikely to be suitable include:

- open wetland habitats of significant conservation value, including winterbournes, some small ponds, exposed river sediments and where protected or priority species are dependent on open conditions (e.g. water vole and great crested newt), or when planting could have an adverse impact on adjacent conservation interests, such as breeding waders;
- sensitive landscapes preserved for their open vistas;
- on deep peat or on land subject to prolonged inundation;
- on flood embankments or close to other flood defence infrastructure, unless by consent;
- immediately adjacent to or downstream of properties or infrastructure vulnerable to flooding by the backing up of floodwaters;
- along highly energetic watercourses with high erosion and deposition rates where watercourse channels, shingle banks and banksides are constantly changing, unless advocated as part of a river-restoration plan (these locations are usually better left to natural tree regeneration);
- immediately upstream of culverts and bridges vulnerable to blockage by fallen trees and woody debris, causing local flooding;
- on shrinkable clay soils near to underground services or the built environment;
- areas containing or adjacent to significant heritage features.

Woodland design

The general aim should be to create naturally functioning riparian woodland habitat comprising a mix of native tree and shrub species or other ecologically appropriate broadleaved trees of various heights. The desired amount of tree cover will depend on location and local objectives, ranging from a closed woodland canopy extending to the bankside to a more open, patchy cover or a mosaic of woody and herbaceous vegetation.

At a local scale, there is a need to retain open areas to protect botanically rich ground-flora communities (e.g. springs, flushes and larger wetlands), to provide access to watercourses, to protect pockets of deep peat, as well as to maintain some open stretches of watercourse and standing water (e.g. to support fish-spawning gravels or protect littoral vegetation communities).

The riparian zones around standing waters such as lakes and ponds may benefit from a more patchy and open tree cover, especially along gently sloping margins. These can form distinctive plant successions transitioning from increasingly open riparian woodland with scattered shrubs to sedge meadow, reed grasses and, finally, floating and submerged aquatic plants. Small ponds are particularly vulnerable to over-shading and thus planting should be varied according to the needs of pond species. Where multiple ponds are present, it would be desirable for some of these to be surrounded by riparian woodland and others left fully open to provide a diversity of habitat conditions.

Riparian woodland is generally unsuited to productive management in view of habitat value, site vulnerability and the risk of water pollution, although some circumstances may necessitate timber harvesting. This includes maintaining nutrient uptake and removal to prevent nutrient saturation and water pollution, although the priority should always be to reduce nutrient sources by implementing good practice.

There are several key points when planning new riparian woodland:

- Determine the extent and condition of existing riparian habitats, the presence of dependent protected and priority species, the status of the water environment and the nature of local environmental pressures, including the level of diffuse pollution and browsing, as well as the presence of invasive species.
- Determine the objectives for creating or restoring riparian woodland, identify appropriate riparian buffer areas and design woodland accordingly in balance with other riparian habitats.
- Integrate existing remnants of riparian woodland and assess the scope to connect with adjacent woodlands, including by extending planting along tributary watercourses.
- At a catchment scale, look for opportunities to work in partnership with landowners and interest groups, including the Rivers Trust and the Wildlife Trusts, to create an extended network of riparian woodland.
- Take account of heritage features. Consult with the relevant statutory historic environment authority to check for the presence of designated heritage features and seek advice from local historic environment services. Where features or areas have been identified, it will often be appropriate to safeguard them within an area of open space.

Woodland extent

Once a suitable site has been selected and local objectives agreed, the first step will be to identify the natural boundaries of the riparian zone. This will determine the potential extent of riparian woodland planting. The limits of the riparian zone can be found using a mix of topography, soil, vegetation and flood maps, checked by local observations or a formal survey. Having identified the extent of the riparian zone, the next step is to establish the quality and condition of the existing riparian habitat and thereby the acceptable level of woodland cover. This may necessitate a change of objectives and design, depending on local circumstances.

Another important consideration is whether the aim is solely to create riparian woodland or if planting is part of a wider woodland creation scheme. Wider planting could enable the riparian woodland to be connected to existing or new woodland on the adjacent land, as well as to potentially enhance the overall water protection function by increasing the extent of tree cover.

Recommendations on the extent of riparian woodland planting include:

- Try to fit planting naturally within the landscape and follow the form of the watercourse or water body and valley sides; the outer woodland edge should be irregular and scalloped.
- Extend planting to the upper break of slope where the riparian zone and active floodplain is <10 m wide and abutted by steep valley sides, and link with any adjacent woodland.
- Where appropriate, extend planting along watercourses and into headwater areas to enhance water benefits at the catchment scale, including to reduce the risk of downstream flooding.

Riparian buffer areas

A riparian buffer area is required to protect all permanent watercourses and water bodies from land-management activities on the adjacent land. For both new and existing forests, the UKFS prescribes minimum buffer widths that incorporate the functioning riparian zone and often extend beyond it (Box 2). The riparian zone of headwater streams will typically vary in width from a few metres up to 10 m and therefore the buffer area is likely to include variable extents of riparian woodland and woodland outside the riparian zone.

Wider riparian buffer areas might be required by a regulatory body as a condition of consent or permit (and this might be to address other interests such as a nearby priority habitat, private

Box 2 Riparian buffer areas

The desired extent of the buffer area should be guided by the sensitivity of the location, the status of the water body and the nature of local pressures acting on the water environment. The UKFS-recommended minimum widths of buffer areas from the forest edge to the bank top of the waterbody or the edge of standing water are:

- 10 m along permanent watercourses with a channel less than 2 m wide;
- 20 m along watercourses with a channel more than 2 m wide and along the edge of lakes, reservoirs, large ponds and wetlands;
- 50 m around abstraction points for public or private water supply, such as springs, wells, boreholes and surface water intakes.

These minimum buffer widths, or minimum working distances, are a Good Forestry Practice Requirement and apply to all forestry activities, except for hinge mounding, inverted mounding and the direct planting of broadleaved trees and native shrubs to create riparian woodland (the planting of native conifers may be appropriate within riparian buffer areas in some countries to restore or enhance native pinewood habitat). They apply on both sides of the watercourse and around the whole perimeter of the waterbody, as well as to all waterbodies, including connected ditches and drains, wetlands, large ponds, lakes and reservoirs. Ditches and drains that are disconnected from a watercourse and so do not carry water into them do not require a buffer area.

Narrower widths of buffer area might be appropriate along minor watercourses with a channel less than 1 m wide, especially on steep ground. The UKFS takes this pragmatic approach to minor watercourses to accommodate situations where, on the one hand, they could be valuable habitats such as spawning streams, but in other situations they may be ephemeral drains leading to a watercourse.

water supply, designated site or historic environment feature). They may also apply where the primary objective of planting is to control the run-off of diffuse pollutants from the adjacent land. Larger pollutant loads can necessitate the use of broader buffers, although this is tempered by the need to minimise land take. The effectiveness of the buffer area for reducing pollutant run-off depends on many factors, including the type, form and quantity of pollutant, and its pathway of movement. See Further reading and useful sources of information on the effectiveness of buffer areas for reducing diffuse pollution.

The wider buffers required to remove nitrate and especially dissolved phosphate pollutants draining the adjacent land may not be compatible with maintaining some land uses. This highlights the need to also reduce pollutant sources by continuing to improve land-management practices. For other pollutants, such as sediment and sediment-bound phosphate or pesticides, the UKFS minimum buffer widths are likely to be effective at preventing these from polluting the water environment, as well as for water cooling, bank protection and intercepting airborne pollutants. Policy and guidance on buffer widths varies between countries and sectors, and may include minimum widths and areas eligible for grant payments. Wider riparian buffers may qualify for payments under country agri-environment schemes, increasing the scope for riparian woodland creation.

Buffer areas can also incorporate other design elements, such as grass strips or physical barriers, including raised bunds. 'Engineered' buffers build on the '3D concept' of modifying the buffer area to intercept and remove diffuse pollutants moving below ground in soil drainage, over the ground in surface run-off and/or above the ground within air flow. Engineered buffers represent complex designs for tackling problematic sites with high pollutant pressures and are not considered further here (see the Environment Agency report, *3D buffer strips: Designed to deliver more for the environment*).

Recommendations on the design of riparian woodland buffer areas include:

- Observe the buffer-width specifications in the UKFS for protecting riparian and aquatic zones (Box 2).
- When designing buffer areas to reduce diffuse pollution from the adjacent land, consider the type, form and quantity of pollutant, as well as its pathway of movement.
- Extend woodland planting beyond the UKFS-specified minimum buffer widths where pollutant loads and run-off volumes from the adjacent land cannot be reduced sufficiently by good management practices; vary the width to be widest downslope of main or convergent surface run-off pathways.
- Plant on both sides of watercourses where possible to enhance riparian woodland habitat and protect waters from land-use activities on adjacent land.

Woodland structure

The desired structure of riparian woodland will depend on local objectives and site sensitivity. Where it is appropriate to establish riparian woodland within the riparian zone, the general aim should be to create fully functioning, riparian woodland habitat. This will usually extend to the bankside and comprise a multilayered canopy structure with three or more vertical layers (ground flora, shrub layer and tree canopy).

> The structure of riparian woodland should be adjusted to reflect a natural transition to areas of adjacent open habitat and the needs of protected species.

The key points are:

- Adjust tree planting and spacing to favour the creation of a multilayered woodland canopy that provides sufficient light to support a rich herb and shrub layer, especially on banksides.

- Design the structure of riparian woodland to naturally transition into areas of adjacent woodland or open habitat, with the latter bordered by an open woodland canopy edge and shrub zone.
- Restrict planting to native tree and shrub species or other ecologically appropriate broadleaved trees within riparian buffer areas and follow country guidance, where relevant, on tree spacing and layout.
- Where a key objective is to intercept diffuse pollution from adjacent farmland, consider closer tree spacing within the buffer area but outside the functional riparian zone to promote pollutant removal (Box 3). Leave a 1–2 m grass strip along the upper edge of the buffer area to enhance sediment trapping.

Box 3 How woodland structure within buffer areas affects pollutant capture

Woodland structure can strongly affect the ability to intercept and remove diffuse pollutants in airflow or surface run-off from the adjacent land. Consequently, the structure should be designed to reflect the dominant pollutant(s) and pathway of movement. For air pollutants such as ammonia or pesticide spray drift, an open outer woodland edge will encourage the movement of air into and through the woodland, while a multilayered main canopy will prevent rapid throughflow and aid pollutant capture. For soluble pollutants in surface run-off like nitrate and phosphate, closer tree spacing will generally promote tree nutrient uptake and encourage soil infiltration and thereby soil retention. By contrast, the trapping and removal of sediment and sediment-bound pollutants in surface run-off are enhanced by a thick cover of ground vegetation, supported by a lighter and more open tree canopy. However, sedimentation is also aided by increased soil infiltration and surface roughness associated with closer tree spacing.

Planting stock

Riparian woodland typically comprises wet woodland species, often dominated by alder, birch and willow (see UKFS Practice Guide 8, *The management of semi-natural woodlands: Wet woodland*). The floristic community of a mature wet woodland will reflect the soil moisture, base-richness and nutrient status of the site (Box 4). Natural regeneration or colonisation should be the preferred method of riparian woodland creation where there is a good chance of this succeeding (e.g. on sites with low browsing pressure and already reverting to native woodland). Where it is unlikely to succeed, select tree species that are well adapted to conditions on the site.

Natural regeneration and colonisation

Natural regeneration and colonisation will generally result in a more natural appearance than new planting, but are dependent on a local or upstream seed source and the use of fencing or strong herbivore control. The points to note are:

- Natural regeneration and colonisation are likely to be less suitable where there is a poor seed source or this is dominated by one or two tree species. However, species composition and stocking can be altered using enrichment planting to help achieve the desired design.
- Wet woodland specialists typically produce large quantities of viable seed when sexually mature and thinning may be necessary to provide enough light to support a rich ground flora.
- Where fencing is not appropriate or would be too expensive, consider using tree

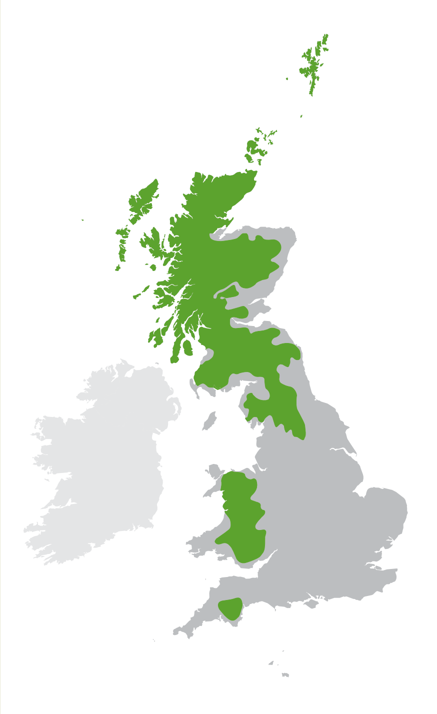
The Forest Research Ecological Site Classification tool provides guidance on which species would be most suitable for the local soil and climate.

Box 4 Riparian woodland habitat in the uplands and lowlands

On upland hill slopes, particularly in the northwest, the National Vegetation Classification (NVC) woodland type W7 (alder–ash woodland with yellow pimpernel) forms the archetypal riparian woodland community. The woodland is characterised by having an open and irregular canopy comprising a mix of trees and shrubs. Restoring this woodland type is increasingly challenging due to disease risk (see the latest country guidance) and planting should favour other component species, such as willow close to the riverbank and oak towards the drier edge of the riparian zone.

An example of a W7 riparian woodland fragment – mixed upland broadleaves beside a small stream in the Wood of Cree, Galloway.

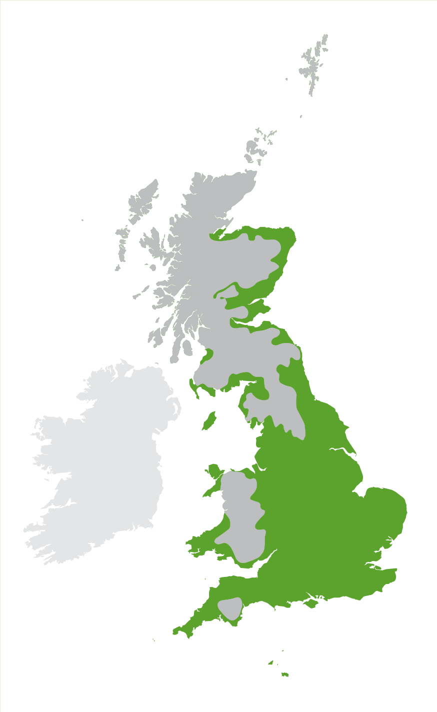
Distribution maps of W7 riparian woodland in Great Britain.



In the lowlands, the NVC woodland type W6 (alder woodland with stinging nettle) is most suited to alluvial terraces of large river valleys, particularly on ex-agricultural land. On smaller watercourses, the riparian woodland canopy can be dominated by almond willow, common osier and purple willow shrubs, which can be planted in patches around blocks of alder to increase light levels and support ground flora. The woodland floor is naturally dominated by nettles, goose grass and great willow herb, plus common reed along the water margin.

Wet woodland priority habitat occurs widely throughout Northern Ireland and includes both NVC woodland types W6 and W7. However, W1 (willow woodland) is the most widespread, and W4 (wet woodland dominated by birch (*Betula* spp.) is also common, occurring on nutrient-poor peat soils.

Distribution maps of W6 riparian woodland in Great Britain.



An example of a W6 riparian woodland fragment – common alder with stinging nettle.

shelters or vole guards to protect trees from browsing damage; the use of plastics, whether made from oil- or bio-based polymers, should be avoided or reduced as much as possible. When redundant, tree shelters and vole guards should be removed as soon as feasible to avoid the impacts of bio-accumulation in the forest soil and, where appropriate, recycled.
- Natural regeneration and colonisation are less likely to be suitable when the primary objective is to mitigate or control diffuse pollution from the adjacent land, which may require faster, closer, more uniform or targeted woodland establishment.

New planting

Riparian woodland creation through planting provides more control over species selection and design to meet specific objectives:

- Select tree and shrub species that are well adapted to conditions in the riparian zone; the National Vegetation Classification (NVC) and UKFS Practice Guide 8 can be used to guide species selection (see Appendix 1).
- Adjust the use of tree and shrub species to suit the natural capacity of the location and, where appropriate, to achieve a multilayered canopy, with sufficient light to support ground flora, especially on banksides and shorelines, and within areas transitioning to adjacent open habitats.
- Select a mix of native tree and shrub species, or other ecologically appropriate broadleaved trees, to provide a diverse leaf litter and extended food supply for aquatic life. Use native conifer species where appropriate to match the site type, add diversity to habitat and landscape, as well as potentially increasing the capture of diffuse pollutants.
- Adjust species selection to match or transition to conditions outside the riparian zone within riparian buffers or on the adjacent land.
- Order tree planting stock that meets the size and condition recommendations in British Standard 3936: Part 4: 2007.
- Select a mix of slow and fast growing riparian woodland species to achieve the desired woodland structure and local objectives; see the Further reading and useful sources of information section for a publication on establishing robust species mixtures.
- Use a higher proportion of shrub species (including elder, blackthorn and hawthorn) on banksides and shorelines to avoid excessive shade, particularly along small stream channels (<5 m wide) and around ponds.
- Plant more flood-tolerant tree species in areas frequently inundated by floodwater (see the 'FORWARA' guidance in the Further reading and useful sources of information section).
- Refer to the latest country guidance on the planting of ash and alder, adjusting the planting mix accordingly (Box 5 and Appendix 1).

Site preparation and establishment

Some form of site preparation may be needed to assist the establishment of riparian trees, but only a limited number of activities are permitted within riparian buffer areas. When planning management activity, it is important to check for the presence of protected and priority species using trusted data sources, and then confirm via site assessment prior to commencing operations, in accordance with country guidance (see the Managing for wildlife section). Conditions are likely to be conducive to rapid weed growth, especially on ex-agricultural land.

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The UK Forestry Standard allows the use of hinge and inverted mounding within riparian buffer areas.

Box 5 The use of common alder in planting riparian woodlands

Alder is a common, native riparian tree species, naturally occurring from sea level to 500 m. It is deep rooted and particularly effective at stabilising banks and preventing erosion. Exposed bankside roots provide an important habitat for aquatic life, including shelter for fish and holt sites for otters.

Alder is a pioneer species and commonly associates with willow, birch, ash, hazel and bird cherry, but it can also occur in pure, even-aged stands that can cast heavy shade. It is capable of rapid initial growth, assisted by its symbiotic association with the nitrogen-fixing bacterium *Frankia*. However, nitrogen fixation can enhance nitrate leaching and, in acid-vulnerable catchments, can result in increased surface water acidification. For this reason, the UKFS recommends limiting the planting of alder to <10% cover within riparian zones along water bodies failing, or at risk of failing, good status due to acidification (see UKFS Practice Guide 23).

Alder is also prone to disease caused by an algae-like organism called *Phytophthora alni*. Since it was first discovered in 1993, this disease has become widespread and is estimated to affect 20% of alder trees in the UK. The symptoms are typically small, yellow, sparse leaves in thin crowns with dead twigs and branches and tarry patches of black or rusty coloured exudate on the trunk. There is evidence that the pathogen spreads into the wild from nurseries and it is important to check nursery stock for symptoms before use. Riparian owners should consider the disease risk and avoid planting alder on riverbanks where diseased alders are present. Extreme care should be taken not to introduce the fungus to remote riparian sites, where alternative species, such as willow, should be planted and natural regeneration or colonisation relied upon to introduce alder to such locations (Figure 9). Where diseased alder trees are present, consider coppicing to aid regeneration.

Figure 9 Alder should not be planted on riverbanks where diseased alder is present, such as this example affected by *Phytophthora*.

Cultivation and drainage

Cultivation should only be used where it is necessary to achieve woodland establishment and avoid areas of deep peat. The only cultivation techniques permitted within riparian buffer areas are hinge or inverted mounding. No drainage is permitted and all drains on the adjacent land need to stop short of the buffer area (as described by UKFS Practice Guide 25, *Managing forest operations to protect the water environment*). On flat terrain, this will cause water to back up onto the adjacent land, which may not be acceptable, impacting on flood risk and land-use management. Where acceptable, extend planting to create a wider area of wet woodland or open wetland habitat.

Planting

- Plant trees while dormant into frost-free ground.
- Use the notch planting method for bare-rooted or cell-grown stock. This involves making a T-shaped notch with a spade, either directly into the ground or into a cultivated soil mound, placing the tree root well down into the hole, withdrawing the tree until the root collar is at soil level and then firming the ground gently with a foot to ensure contact between the roots and the soil.

Pesticides and fertilisers

Pesticides and fertilisers should not be used within buffer areas, including the use of urea and PG (*Phlebiopsis Gigantea*) suspension as stump treatments.

- Use non-chemical methods of weed control to aid the survival of newly planted trees, such as mounding or the use of mulch mats.
- If herbicide use is unavoidable to control invasive non-native species, applications must be limited to products approved for use in or near water, which may require formal consent from the water regulatory authority.
- Insecticides should not be used within riparian buffers, including the dry planting of pre-treated trees or top-up spraying.
- Fertilisers should not be stored or applied within riparian buffer areas, including hand applications of inorganic fertiliser.
- Ensure that aerial fertiliser applications to the adjacent land avoid fertiliser drift onto riparian buffer areas; this may require doubling buffer widths, especially where waters are nutrient sensitive.

Fencing and tree guards

Riparian zones can attract deer and other grazers, as well as forming an important conduit for animal movement. New planting and new growth of managed coppice stems are therefore likely to require some form of protection, unless there is very strong control of browsing pressure. It will generally be impractical to fence off riparian buffer areas within new and existing forests, except for dedicated riparian woodland-planting schemes:

- Use vole guards or tree shelters where vole, rabbit or deer damage is likely to be significant and cannot be controlled by silvicultural techniques (Figure 10).
- Plastic vole guards and tree shelters should not be used where there is a significant risk of these being detached during flood or storm events and washed downstream.
- Where it is appropriate to use plastic vole guards or tree shelters, select the minimum size

Figure 10 Along Carrock Beck (River Eden catchment, Cumbria), young saplings have been protected from grazing animals by using tree shelters.

of shelter necessary to protect the tree from the grazing pressure (20 cm is usually adequate for voles and rodents; 60 cm for rabbits; and 90 cm for small deer).

- Consider the visual impact of tree shelters and plant in wavy rather than geometric lines.
- Collect vole guards and tree shelters once the trees are established to prevent bio-accumulation and contamination of buffer areas and watercourses by plastic; if left, plastic guards and shelters will become brittle and break into small plastic fragments that are difficult to remove and can wash into streams. Collected plastic should be recycled where appropriate.
- Check with the relevant flooding authority regarding regulatory requirements for fencing, drinking bays or other structures in or near watercourses, which may require consent.
- Erect stock-proof fencing where riparian woodland is accessible to livestock. The fence should be external to the full width of the riparian buffer and may need to extend along both sides of smaller watercourses to prevent livestock from crossing to browse the opposite side.
- Use line and wire rather than netting for fences in flood-prone areas to reduce the quantity of flood debris and litter caught by the fence. The fence should run parallel to the watercourse to minimise the accumulation of debris and reduce flood damage.
- Fences should not straddle wider watercourses. Where this is not possible, hanging water gates should be used, which may need consent (Figure 11).
- Check fences and water gates regularly, especially after high flows.
- Create weak links in fences within floodplains to give way under moderate pressure and prevent failure of the entire fence. These 'sacrificial' sections minimise the time and cost of flood repairs.
- Include points of access on formal and informal footpaths to accommodate established public use and minimise damage to fencing. Select the least restrictive option.

Ideally, water troughs and field pumps should be used to provide water for livestock on the adjacent land. However, where this is not feasible, fencing will need to be designed to allow controlled access to the watercourse. Access points should ideally be located on the inside of bends, which are usually shallower and less prone to erosion. Where possible, position the fence so the stock can reach their heads under the fence to drink, but cannot get their hooves in the water (Figure 12).

Figure 11 Hanging water gates should consist of a series of wooden droppers attached to a length of wire cable or a round wooden rail that is suspended horizontally between the straining posts. Each gate should be constructed to fit the profile of the individual stream. Scottish Highlands.

Figure 12 New cattle watering point designed to reduce damage to riverbanks and minimise pollution. Powlair, Finzean, Aberdeenshire.

Roads and tracks

- Build new roads and tracks outside of riparian buffer areas wherever possible.
- Avoid fording rivers and streams unless there is an existing purpose-built ford and measures are taken to avoid the risk of water pollution; seek advice from the water regulatory authority.

Restoring riparian zones within conifer forests

Considerable progress has been made in removing non-native conifers from previously planted riparian zones, although some stretches of watercourses remain to be cleared. A greater issue is the lack of progress in restoring riparian broadleaved woodland within buffer areas where conifers have been removed, with many forming poor quality open habitats impacted by felling brash and conifer regeneration. A key objective of the forest-management plan should be to encourage the establishment of locally native tree and shrub species or other ecologically appropriate broadleaved trees within riparian buffer areas, supported by enrichment planting where required. There is also a need to control the spread of invasive non-native species where feasible. Restoration efforts are best targeted to priority locations informed by site sensitivity, water status and local pressures.

Riparian zones are very susceptible to ground damage by trafficking and should be protected from disturbance.

The points to consider are:

- Consult with appropriate organisations such as the water regulatory authority and local fishery bodies to help prioritise watercourses and standing waters for restoration work.
- Prioritise watercourses recovering from acidification or lacking shade for the removal of riparian non-native conifers and to encourage the establishment of riparian broadleaved woodland.
- Where riparian conifers remain to be cleared, consider the scope for a managed transition to riparian broadleaved woodland by progressive thinning to maintain continuous woodland cover; some priority species such as freshwater pearl mussel can be adversely affected by the sudden and complete removal of shade.
- Where possible, clear conifers from riparian buffers and fell adjacent stands before trees mature and set seed (Figure 13).

Figure 13 Stream side cleared of young regenerating Sitka spruce, with the previous plantation having extended up to the water's edge. Forest of Ae, southwest Scotland.

- Retain existing riparian broadleaved trees, especially old and decaying trees.
- Do not permit trafficking by harvesting machinery (especially loaded forwarders) within buffer areas, except for appropriately designed watercourse crossings.
- Use long-reach harvesters to fell and remove trees, with any out-of-reach trees extracted by winching or left to create deadwood, especially within the riparian zone.
- Felled trees and timber stacks should not be left within riparian zones (unless temporarily for the purpose of creating or constructing leaky woody dams), especially where the washout of these poses a flood hazard.
- Fell trees away from watercourses to avoid damaging banksides and the water channel.
- Replace upturned root plates wherever possible to restore banksides.
- Machine-mounted flails should not be used to clear conifer regeneration within riparian buffer areas. Remove young trees by hand or, for bigger saplings, cut below the lowest live branch with a bow saw, brush cutter or chainsaw.
- Monitor conifer regeneration within cleared riparian buffers and repeat clearance until riparian broadleaves are established (Figure 14).
- When restoring riparian zones, pesticide applications should not be used within buffer areas.
- Keep watercourses and buffer areas clear of brash as far as practicable; process felled trees outside of the riparian buffer and especially the riparian zone.

Figure 14 Conifer regeneration needing removal before impacting on riparian woodland restoration.

Managing riparian trees and woodland

Riparian woodland and riparian buffer areas are generally unsuited to productive management unless the primary objective is to reduce diffuse pollution from adjacent agricultural land. The focus of riparian woodland management should be to encourage natural processes to restore, protect and maintain riparian and aquatic habitats, achieving the desired structure of riparian woodland habitat and protecting retained open habitats (Figure 15). Any work should align with country guidance and be guided by an appropriate site assessment.

Care in tree species selection, site preparation and planting layout will generally reduce the need for management intervention. The most common problems are likely to be securing the establishment of riparian broadleaved woodland and controlling conifer and Invasive Non-Native (or 'alien') Species (INNS) regeneration. The sensitivity and vulnerability of riparian buffer areas mean that management will mainly involve low-intervention silvicultural methods. Management objectives should be written into the forest-management plan and progress towards achieving those objectives must be monitored. The combined riparian zone and buffer area should be delineated in the plan as a water-protection zone and managed as a long-term forest structure, comprising a patchy mosaic of linked habitats.

Enrichment planting, manual thinning or bark ringing, and browsing control will be the main ways of securing and maintaining the desired riparian woodland habitat and level of shade. Minimal management may be appropriate within riparian wet woodland habitat, although consideration should be given to the need to moderate the level of shade through crown thinning or coppicing (Figures 16 and 17). Traditional coppice management (on appropriate

Figure 15 Management to enhance riparian woodland.

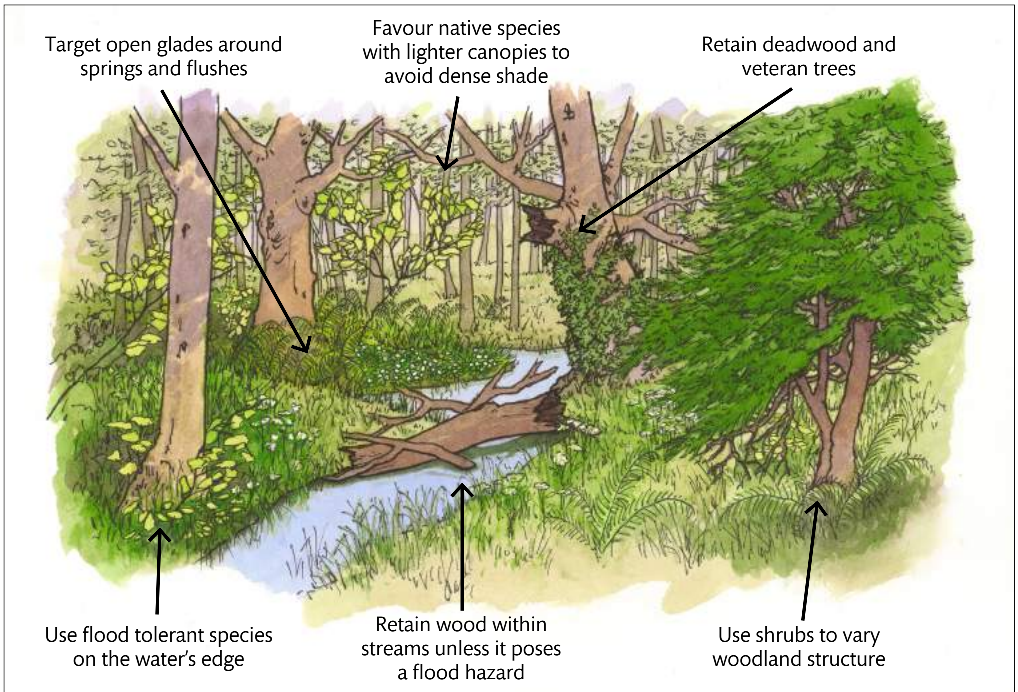


Figure 16 Pollarding has been used in the past in this example from the River Enborne in North Hampshire to create more dappled shade over the watercourse and riparian zone.

Figure 17 Selective thinning of mature alder using high coppice cuts to create more dappled shade over watercourse. Powlair, Finzean, Aberdeenshire.

species) is likely to be restricted to specific sites where such repeated interventions are warranted (e.g. to support priority species). The same applies to pollarding, which will be driven by the need to manage bankside conditions along key watercourses and access routes.

Alternative techniques include 'hinging' of bankside trees, whereby stems are partially severed in a manner similar to hedge laying and pinned against the riverbank to reduce erosion and vary water flows. Particular care is required to protect veteran trees, especially those with cavities used by bats and nesting birds.

Thinned trees can be felled and left within riparian zones to create deadwood where this will not pose a flood hazard due to the blocking of downstream bridges or culverts. Burning of thinnings should be avoided and mechanised harvesting limited to trees within reach of machinery situated on the adjacent land. Otherwise, felling will mainly involve manual chainsaws, with tree extraction by winching, taking care to protect soils and ground vegetation. Aside from where there is a need to protect open habitats, the core riparian zone should generally be left to develop and retain riparian woodland habitat.

Productive management of riparian woodland buffer areas for maintaining tree nutrient uptake for pollution control should largely be limited to trees within easy reach of harvesting machinery on the adjacent land or suitable for coppicing. If there is a need to enhance the buffer function, this is best done by widening the area of planting onto the adjacent land. Any timber harvesting would need to be phased and potentially involve strip cutting to maintain pollutant uptake and removal between felling years. The alignment of fencing would need to reflect future management operations.

Examples of riparian woodland management are displayed in Figure 18.

Figure 18 Different examples of management action to improve riparian woodland guided by local circumstances and management objectives.

a) Progressive conversion of riparian non-native conifer to a riparian broadleaved woodland mosaic through gradual thinning.

b) Development of a young, native riparian broadleaved woodland by controlling conifer regeneration.

c) Strong, native broadleaved regeneration following conifer removal; mature Scots pine retained to benefit the riparian zone.

d) Riparian zone managed as an open canopy of native broadleaved woodland for multiple benefits.

e) Non-native conifers ring-barked to aid conversion to riparian broadleaved woodland.

f) Ongoing clearance and redesign of non-native conifer plantation to aid restoration of riparian habitat.

g) Absence of ground vegetation within the riparian zone resulting from excessive grazing pressure.

h) Lack of riparian woodland regeneration and absence of understorey due to grazing pressure.

Managing deadwood and leaky woody dams

Deadwood plays a very important role in the ecological functioning of riparian woodland and the aquatic zone, providing an energy source and structural habitat for a wide range of species. It can also form leaky dams and log steps within stream channels, diversifying water flows and increasing oxygenation. Deadwood contributes both positively and negatively to flood risk by slowing the flow or blocking downstream structures respectively (specific guidance is available in UKFS Practice Guide 27, *Designing and managing forests and woodlands to reduce flood risk*). The future supply and management of deadwood is an important consideration in the design and management of the riparian buffer area, informed by local factors (e.g. the nature of flood risk) and objectives:

- Any work in or adjacent to a watercourse requires consent.
- Existing features such as embankments, sluices and weirs may have important historic and cultural value and need to be protected.
- Retain deadwood and standing dead and fallen trees within the riparian buffer area and watercourses, unless they pose a significant risk of washout and damaging or blocking downstream structures.
- Undertake a nesting bird and bat survey before disturbing any standing deadwood.
- Where appropriate, leave riparian woodland to develop naturally and age accordingly to sustain deadwood inputs.
- Consider adding large woody material to watercourses to restore and improve freshwater habitat where flood risk is not an issue, guided by local fishery bodies and conservation agencies (obtain consent where appropriate) (Figure 19). Do not use veteran, diseased or dead trees.
- Where appropriate, consider constructing leaky woody dams within watercourses <5 m wide and across the riparian zone and active floodplain to attenuate flood flows and reduce the risk of downstream flooding. Consider potential hazards and remove or secure dams where they pose a flood risk. Refer to UKFS Practice Guide 27 for more details and comply with relevant licences and permissions.
- Remove blockages from watercourses caused by conifer brash dams, taking special care where these are filled with sediment; seek advice from the water regulator or flooding authority.

Figure 19 Use of large woody material to improve freshwater habitat by deflecting flows and reducing bank erosion in Pickering Beck in North Yorkshire.

Managing for wildlife

Several protected and priority animal species use or rely on riparian habitat. Before any work commences, it is important to undertake at least one appropriately timed field survey to check for their presence and adjust management practice accordingly. Woodland managers must familiarise themselves with country legislation and guidance on managing woodlands that do, or may, contain protected species, including whether a species licence is required for planned works. It may be an offence to disturb a protected species or affect any structure or place that it uses for shelter, protection, resting or breeding, whether or not deliberately or recklessly. Specific guidance for riparian habitat management to conserve some key species is provided below.

Birds

Riparian woodland supports a number of riparian bird specialists, such as the grey wagtail (*Motacilla cinerea*), dipper (*Cinclus cinclus*), kingfisher (*Alcedo atthis*) and grey heron (*Ardea cinerea*). There are also several conservation priority species particularly associated with wet woodland, including the lesser redpoll (*Acanthis cabaret*), spotted flycatcher (*Muscicapa striata*), wood warbler (*Phylloscopus sibilatrix*), willow tit (*Poecile montanus*) and lesser spotted woodpecker (*Dendrocopos minor*). While new planting is likely to benefit these species, it can potentially threaten others associated with open wetlands, particularly breeding waders such as the golden plover (*Pluvialis apricaria*), curlew (*Numenius arquata*) and the dunlin (*Calidris alpina*). Therefore, a balance must be struck between riparian woodland and open wetland bird habitats, both of which need active restoration and expansion. All wild bird species are protected during the breeding season, with some species receiving additional protection. Operations must be planned and timed to avoid disturbing nesting birds.

Habitat-management actions

The habitat requirements of different bird species are varied. Depending on the quality of riparian habitat and density of the species of interest, it might not be appropriate to encroach onto open wetland habitat. Expert advice should be sought, and attention paid to any local and regional guidance. Where riparian woodland already exists or can be created, it should be managed to support the species known or expected to use the site. Retain large, old and veteran trees to ensure provision of suitable sites for cavity-nesting birds. If planting riparian woodland, aim to create a varied woodland structure of wet woodland tree species, particularly alder, birch and willow.

Bats

All British bats are protected species; their breeding sites and resting places are also fully protected by law. Most bat species use woodland habitat to a degree, and many use deciduous woodland for roosting, foraging and hibernation. Young (<20 cm stem diameter), unthinned, productive conifers are unlikely to be used for bat roosts, but bats can roost in older conifer woodland, especially in mature Scots pine trees. Riparian habitat within or adjacent to woodland is favoured by the barbastelle (*Barbastella barbastellus*), Daubenton's bat (*Myotis daubentonii*), Leisler's bat (*Nyctalus leisleri*) and the pipistrelles (*Pipistrellus pipistrellus*, *Pipistrellus nathusii* and *Pipistrellus pygmaeus*), particularly in association with suitable roost sites such as rotten cavities and woodpecker holes in mature trees, and open water for hunting.

Daubenton's bat (*Myotis daubentonii*) is especially associated with riparian woodland. Riparian woodland corridors are also significant in terms of wider landscape connectivity for species such as lesser horseshoe bats. Bats are widely distributed but populations are much smaller in upland and coastal areas compared with inland lowlands.

Habitat-management actions

- Protect all existing bat-roost sites, which is a legal requirement. Retain standing deadwood, as well as large and old trees, to ensure a succession of roosting opportunities. While a tree of any age with cracks and crevices has the potential to host bat roosts, there is a reasonable chance that trees aged >80 years will contain a bat roost, and a high probability if trees are aged >120 years.
- If a roost is identified, avoid mechanised felling or thinning riparian trees within 20 m of roost sites. Hand felling could be undertaken with the advice of an experienced bat ecologist, and may be necessary to reduce the level of tree competition impacting on ancient and veteran trees.
- Create and maintain riparian habitat diversity, comprising a mix of open habitat for foraging and riparian broadleaved woodland cover for shelter and roosting.
- Connect riparian woodland with adjacent woodland cover and old hedgerows to aid bat movement within the landscape.

Otters

The European otter (*Lutra lutra*) is widely distributed in many river systems across the UK with sufficient fish stocks (Figure 20). They prefer sites that are undisturbed by humans, ungrazed by livestock and rarely flooded. An otter home range extends up to 200 m from the water's edge and 10–50 km along a linear watercourse, including ditches and small streams, which are used as corridors and foraging habitat. In non-linear situations the range can be between 29 ha for males and 34 ha for females. Breeding sites are areas of habitat that provide a breeding female

Figure 20 Otters are intolerant of disturbance.

with suitable conditions for her to establish a natal den. These conditions include security from disturbance, an absence of flooding, as well as access to a good food supply and play areas for cubs. They may breed during any month of the year. The otter is a European Protected Species (EPS) and, as such, woodland practices must comply with the laws that protect them and their resting places (couches) and more permanent dens (holts).

Habitat-management actions

- If an active breeding site is found, establish an operational exclusion zone of 200 m (unless it can be shown that topography and local circumstances allow for a smaller zone, of 100 m minimum). A 30-m operational exclusion zone should be marked around all other resting places and operations in this zone should be avoided. If management operations are necessary within the exclusion zone, you must apply for and obtain a licence before starting operations.
- As otters are most active at dusk and dawn, avoid operations within the vicinity of otter shelters within two hours of sunrise and sunset; this is reduced to one hour between November and February (inclusive) because of the limited daylight.
- Remain alert for potential breeding (natal) sites that would satisfy the habitat requirements for an otter to establish a natal holt. If a potential breeding site is identified, seek specialist advice.
- Maintain ample cover around sites being used or with potential for use as natal holts and couches.
- Retain and support the development of mature trees on banksides to provide good habitat (e.g. exposed large roots and hollow trunks).
- Maintain large scrub thickets (patches >0.5 ha) and retain open areas of tussocky or fen vegetation.
- Where possible, leave windblown trees and if suitable den sites are absent, consider creating these such as by leaving log piles (providing these do not pose a downstream flood risk if washed out). Keep timber stacks at least 100 m away from a watercourse used by otters.

Water voles

Water voles (*Arvicola amphibius*) have declined due to changes in land use and habitat management of the riparian zone. This has, in turn, caused fragmented populations that are not conducive to this species' colonial behaviour and this, coupled with predation by American mink (*Neovison vison*), has meant that the water vole is the fastest declining mammal in Great Britain. However, local projects continue to protect extant populations and, where necessary, reintroduce animals to suitable habitats where mink control is taking place. These conservation measures have resulted in localised expansions of their range.

Like birds, there is a need for a careful balance between riparian woodland creation and the requirements of water voles, if present. While riparian trees and shrubs provide an important food source, in general, water voles prefer bankside vegetation such as grasses, rushes, reeds and sedges, with roots, rhizomes and woody stems consumed in the winter. They avoid stream banks that are excessively shaded by dense scrub and trees, which can harbour predators and hinder the growth of their preferred food sources (Figure 21). Water voles can potentially use any wetland habitat, watercourse or pool; they prefer slow flowing water and live in burrows in soft, high banks. The tunnel entrance may be underwater, but the burrow must remain dry and above the water level between March and September. They are highly territorial and, depending on habitat quality, require a home range of 30–300 m length of a linear watercourse.

Figure 21 Water voles prefer lush open bankside vegetation for food and shelter.

Habitat-management actions

- Where water voles are present, manage levels of riparian shade to maintain a 5-m wide open zone of lush vegetation on banksides, composed of reeds, grasses, rushes and herbs to provide food and cover.
- For the next 5 m beyond the bankside open zone, favour the planting of the following tree species that are beneficial to water voles: willow species, aspen, black poplar, common alder, hazel, field maple, rowan, hawthorn, crab apple, bird cherry and elder.
- Where possible, avoid watercourse crossings and disturbance to banksides where water voles are present. If unavoidable, consider the need for mitigation measures and an associated species protection licence.
- Design planting to avoid fragmentation of riparian corridors that link areas of bog, marsh, ponds, ditches or streams.
- Strictly control and, where possible, eliminate mink.

Beavers

By the 16th century, the native European beaver (*Castor fiber*) had been eradicated from Great Britain. Recent reintroduction programmes have re-established beavers across Scotland, while there is a growing number of controlled beaver releases into fenced enclosures in England and Wales; an unplanned release of beavers in the River Otter in Devon has led to a naturally expanding population within the catchment (Figure 22). In England and Scotland, beavers are protected and a licence is required for their release into the wild. Beavers are not protected in Wales but a licence is required for their release into the wild.

The impact of beavers is greatest in the riparian zone, usually extending up to 20 m from the water's edge, but occasionally up to 50 m. Territory size depends on riparian and aquatic habitat quality, and typically ranges from 1.5 to 5.0 km linear length of the water edge. Beavers most often live in burrows on the riverbank or loch shore; however, they will sometimes build lodges where it is not possible to burrow, or on top of burrows to increase weather-proofness or space.

Figure 22 Beavers are increasingly being reintroduced into new areas within fenced enclosures, while established wild populations continue to expand locally.

Lodges are usually made from cut branches, logs and mud (up to 2 m high and 15 m across). They typically build log, mud and stone dams across watercourses to create feeding areas, provide safe refuge and facilitate travel (normally ranging from 0.2 to 3 m in height and from 0.3 to >100 m in length). These dams raise water levels and promote upstream ponding and waterlogging, leading to the death of some trees but favouring the growth of willows and alder.

Beavers are strict herbivores and feed on a wide variety of aquatic and terrestrial herbaceous and woody vegetation. They generally avoid conifer trees and favour riparian broadleaved woodland, which provides a key source of food and building material. Beavers tend to select the most palatable species (willow and aspen) that re-sprout readily, as the regrowth is an important food source. Other species, such as rowan, birch, ash, hazel, dogwood and alder, may also be utilised, particularly where they are the most abundant species. Most tree felling occurs within 10–30 m of the water's edge, where it tends to lead to the loss of older trees over time, resulting in beaver induced coppicing and a young tree age profile. Damaged trees (through gnawing and waterlogging) may fall and threaten the integrity of stock fencing, leading to a high level of deer browsing; this can be problematic because it prevents shoot regrowth and tree regeneration, causing a loss of riparian woodland cover.

Habitat-management actions

- Develop a local beaver-management strategy and catchment plan where beavers are present or there is a planned release. This should consider potential impacts on land use and water users, including flood management, fisheries, agriculture and forestry.
- Where appropriate, establish riparian woodland buffers to aid beaver expansion and management; a 20-m wide buffer is likely to minimise potential beaver conflicts with adjacent land-use interests.
- Encourage natural regeneration or plant ecologically appropriate broadleaved tree and shrub species to enhance beaver habitat.
- Undertake monitoring to assess and understand beaver impacts.
- Where conflicts arise, adopt appropriate management techniques to reduce impacts, such as installing beaver deceivers or fencing to protect mature trees and woodland, flow devices or

dam notches to reduce water levels behind dams, or grilles and rock armour to reduce burrowing into riverbanks. Seek guidance from the conservation authority or local wildlife trust.
- Apply for a licence from the conservation authority if there is a need to remove or alter mature dams (more than two weeks old), install bank protection or control the local beaver population.
- Consider the need to protect vulnerable riparian woodland habitat and tree species from beaver introductions or expansion, such as alluvial woodland, Atlantic hazelwood and aspen.
- Control deer browsing where this is limiting the regrowth and regeneration of riparian woodland trees and shrubs.

Atlantic salmon

Atlantic salmon (*Salmo salar*) require cool, clear, well-oxygenated water and a variety of habitat types to provide in-stream cover, including deadwood, tree roots and undercut banks. They benefit from the protective functions of riparian woodland, including the provision of shade to prevent excessive warming during the summer, especially in smaller streams. Juvenile salmon lifecycle stages are particularly sensitive to water temperature, with rises above threshold ranges having a negative impact on reproduction, growth and survival.

Salmonids benefit from a varied cover of riparian woodland, with the level of optimum shade varying with location, climate and life stage. Excessive shade can reduce fish growth and spawning success, especially in cooler upland areas, while too little shade can result in rivers becoming too hot and salmon experiencing thermal stress during hot and dry summer periods.

Historic tree clearance and overgrazing has left many salmon-spawning streams 'overwide' with unstable banksides due to a lack of riparian vegetation and protective tree root systems. Where appropriate, riparian woodland creation or restoration supported by fencing can remedy these effects and improve water quality. It is important that landowners take particular care when undertaking work close to rivers and streams to minimise the input of any sediment, particularly fine sediment.

Seek advice from local fishery bodies on the presence of salmon and other salmonids, such as sea or brown trout, the location of key spawning sites, what constitutes as excessive shade and on appropriate management work, including timing, to optimise the level of shade and minimise disturbance (see the Keeping Rivers Cool guidance in the Further reading and additional sources of information section).

Habitat-management actions

- Establish riparian woodland where there is a lack of shade and intervene (e.g. by thinning) when excessive shade develops on banksides, especially on southern sides near spawning sites.
- Consider placing and securing log steps and log flow deflectors within watercourses to diversify channel conditions, control bank erosion and encourage intra-gravel currents to wash out fine sediment; obtain consent from the flooding authority, which is a legal requirement.
- Ensure that any leaky woody structures that naturally form or are placed within watercourses do not present a barrier to fish movement.
- Where appropriate and practicable, remove any redundant weirs forming a barrier to fish movement; obtain consent from the relevant water authority, which is a legal requirement.

Freshwater pearl mussel

The freshwater pearl mussel (*Margaritifera margaritifera*) was once widespread throughout the UK but populations have been decimated by pearl fishing, pollution from aquaculture and agricultural run-off, as well as habitat damage. The species is endangered throughout its range, highlighting the need to protect remaining populations. Mussel densities have been found to be positively correlated with the level of riparian broadleaved woodland shade, and woodland creation is a favoured measure to protect and aid the recovery of mussel populations.

The freshwater pearl mussel has a complex life cycle, including a larval stage attached to the gills of trout or salmon before the juveniles and adults become established in the riverbed. The mussel requires clear, well-oxygenated, unpolluted water, good salmonid fish habitat and suitable bed sediments. Adult mussels are found in sand among boulders and cobbles in water that is typically 30–40 cm deep. Mussel aggregations are associated with riparian woodland with stable banks and canopy shade to keep water cool during the summer and reduce aquatic weed and algal growth that can be detrimental to mussel growth and survival.

Habitat-management actions

- Check with the national conservation agency whether freshwater pearl mussels are present within local watercourses. If present, establish and manage riparian woodland buffers to provide appropriate levels of shade and to reduce nutrient and sediment inputs from the adjacent land.
- Ensure that drains on the adjacent land stop at the edge of the buffer to promote the retention and removal of any entrained sediment and dissolved nutrients; existing drains will need to be blocked by damming, infilled, or cut off.
- When harvesting trees within riparian buffers, cut any windblown bankside trees and push back down upturned and exposed root plates to reduce further bankside erosion and sedimentation. Follow UKFS water guidelines to ensure that silt does not enter watercourses during forest operations.
- Retain logs forming stable large woody dams providing these do not form a barrier to fish movement or pose a flood risk if washed downstream; where possible, remove live branches from trees forming large woody dams to make the woody dam more porous and reduce needle retention.
- Where previously removed, consider returning boulders to river channels to help stabilise the riverbed and diversify river flows; seek expert advice and obtain consent from the flooding authority, which is a legal requirement.
- Consider placing and securing log flow deflectors within watercourses to diversify channel flow conditions, control bank erosion and encourage intra-gravel currents to wash out fine sediment; seek expert advice and obtain consent from the flooding authority, which is a legal requirement.

Managing invasive non-native species

Some INNS pose a significant risk of adverse impact and so they are regulated by law. Under devolved statutory instruments there are general duties to protect the environment, society and economic interests from the risks posed by certain, listed, non-native species. There is also devolved legislation, under which it is an offence to release or cause the spread of INNS species, unless authorised. Woodland owners need to consider these legislative requirements when undertaking INNS control work and ensure that all necessary licences and permits are in place, as well as robust biosecurity measures (Box 6). Country guidance should be referred to if available.

Strict restrictions apply to 'species of special concern' so they cannot intentionally (unless permitted/licenced) be transported (except for the purpose of eradication), kept, allowed to be grown, permitted to reproduce or released into the environment. Other legislation makes it illegal (unless under licence) to release or allow to escape certain non-native animals and to plant or cause to grow in wild certain non-native plants. There are also legal constraints on the carriage and disposal of INNS waste material on (e.g. burial or burning of plant material) and off sites within the UK. It may be necessary to register a waste exemption for burning green waste and/or local byelaws may apply (see www.gov.uk/guidance/d7-waste-exemption-burning-waste-in-the-open).

Box 6 Biosecurity measures for forest and woodland-management activities

Biosecurity is a set of precautions that aims to prevent the introduction or spread of INNS, pests and diseases. These species include invasive animals and plants (which may be native or non-native) and other harmful organisms such as tree diseases.

Invasive non-native animals such as the American signal crayfish and killer shrimp, and plants such as floating pennywort, giant hogweed, Japanese knotweed and Himalayan balsam, can cause serious damage to watercourses over large areas. Removal is difficult and expensive.

The eggs and juveniles of invertebrates, and seeds and root fragments of plants, can be trapped in mud and debris attached to people, equipment, vehicles and forest machinery. If not thoroughly cleaned and dried these can be transported to other sites where they may fall off and spread to new watercourses.

Biosecurity best practice

The spread of invasive species can be greatly reduced by thoroughly cleaning vehicles and forest machinery before moving between sites. Cleaning areas should be located away from waterlogged ground, watercourses (including drains) and standing waters to prevent run-off contaminating waters. Hard standing surfaces or gravelled areas are preferable where run-off can drain to nearby ground.

If possible, dry clothing, equipment and machinery for at least 48 hours before use on a new site:

- Arrive with clean vehicles, machines and equipment and disinfected footwear.
- Use clearly marked cleaning stations on site.
- Ensure vehicles and forest machinery are clean before leaving the site – this includes tyres, wheel arches and undersides.
- If it is not possible to wash equipment or machinery on site, use a nearby washdown facility/depot (where the water drains to ground or to the main sewer) to clean and dry items before being sent to a new site.

In the UK, measures are in place to identify potentially problematic species for which action plans have been prepared to deal with any outbreaks. Woodland owners can contribute to this process by checking the National Biodiversity Network (NBN) Atlas website and/or with water regulators about the location of infected sites, and working with other riparian owners and/or local groups to coordinate action. Owners are encouraged to report the presence of any INNS and records of eradication work (through the iRecord website/app or local record centres).

This section provides guidance on good practice to control key invasive weeds of riparian woodland. For existing native and non-native invasive weed species, the best approach is to act quickly to eliminate the first presence before the problem spreads. Non-chemical methods are preferable wherever possible. For small infestations manual control (hand pulling and cutting) may be adequate, depending on the species, but for larger infestations some mechanised or chemical method will be necessary. Heavy machinery is excluded from riparian buffer areas because of the risk of water pollution from soil compaction and disturbance caused by repeated trafficking. Buffer areas may be accessible by machinery operating on the adjacent land, but where this is not feasible herbicide use will be the main option, subject to approval from the regulatory authority. When composting, drying, stockpiling or burning plant material, this should take place in a location where the material will not be washed away by floodwater. Whichever method is adopted, an alternative vegetation type should be established once the invasive weed species has been eradicated. Wider outbreaks will require coordinated action by all riparian owners within a catchment.

A licence may be needed to apply herbicide near water and only certain herbicides are licenced for use in or near water. Check pesticide regulations and guidance for the latest information. Ensure control activities will not negatively impact drinking water supplies or protected species that may be present and sheltering along banks (e.g. otters and water voles) when formulating a management plan. A licence from the nature conservation authority may also be required for mechanical and herbicide methods.

Further information, advice and factsheets on the identification and control of invasive non-native species are available from www.nonnativespecies.org. If in doubt, contact your local regulatory authority.

Giant hogweed

Giant hogweed (*Heracleum mantegazzianum*) is a non-native large perennial species (Figure 23). Protective clothing (e.g. chemical spray-suits, boots, gloves, hoods and face shields) is essential because the plant has toxic sap that causes recurrent persistent skin sensitivity to sunlight. It is recommended that all skin should be covered when managing this plant. If there are other land users or contractors on site it is important to isolate the area and put up warning signs. In cases of exposure to plant sap, skin should be washed immediately with soap and water and kept away from sunlight for 48 hours; subsequently, sunscreen should be used on exposed skin. If sap gets into the eyes, they should be rinsed with water and sunglasses worn for 48 hours. Medical advice must be sought. Care must also be taken in disposing of cuttings and cleaning machinery and clothing because sap remains toxic for some time after cutting. Seeds can survive for up to 15 years but usually only for 5–7 years. Successful control requires a long-term strategy as a one-off treatment is unlikely to be effective. Once eradication is complete, it is recommended that the site is surveyed annually during April–August until three full seasons have passed without regrowth, followed by one further visit two years later.

Figure 23 A single cluster of giant hogweed flowers can produce 50 000 seeds, which remain viable in the soil for up to 15 years.

Mechanical control

Correct timing is important to act before flowering to minimise seed germination (flowering June–August).

For small infestations (<100 plants) where the plant bases are accessible then it is recommended that the tap root of the plant is cut 10–15 cm below the soil surface (preferably in March–April). If the treatment occurs later in the year when the seed heads have started to form, then remove the seed heads before they ripen and ensure that they are securely bagged and disposed of appropriately. If the bases of the plants are not accessible, then consider using herbicide or mowing/grazing.

For larger infestations (>100 plants) then consider if areas further away from the riverbank could be ploughed (preferably before May), which has the benefit of killing the plant and burying some of the seed bank. However, ploughing is likely to need repeating in the following years for effective control.

Mowing can be used to control the plant but will need to start before the seed heads form and be repeated (six times a year for at least two years). Respirators should be worn if powered mowers are used. Cutting along the riverbank will likely need to be done by hand and may be impractical for health and safety reasons.

Grazing starting in the spring each year can also be a useful control measure in rural areas where livestock are present, although this will take 3–5 years to be effective.

Chemical control

The application of herbicide (e.g. glyphosate with a surfactant) is recommended for large stands or where bases are not accessible; obtain consent from the water regulatory authority for use in or near water. It can be highly effective at eradicating young plants prior to flowering (undertaken in March or April). Usually, one application is enough to kill a plant, although an additional respray should be planned in case needed. Where plants have flowered, repeated applications will be required to remove the infestation as the seedbank will lead to further plants appearing. It is recommended that treated areas are reseeded once the plants have died off and new plants spot-treated as they appear.

Disposal

Cut leaves and stems can be composted, while seeds, roots and taproot can be dried and burnt or buried (at least 2 m deep), preferably outside the riparian buffer. Alternatively, plant material can be disposed of at a suitably licenced waste site.

Himalayan balsam

Himalayan balsam (*Impatiens glandulifera*) is an INNS found on damp ground and riverbanks throughout the UK (Figure 24). It is the fastest growing annual plant and can reach 3 m in height. The explosive pods spread seeds up to 6 m from the parent plant.
As seeds can last two years in the soil, control measures will need to be repeated for three years to eradicate an infestation. Once eradication is complete it is recommended that cleared sites continue to be monitored until two full seasons have passed without regrowth.

Mechanical control

Himalayan balsam is a shallow rooted species and, for small infestations, hand pulling before flowering is highly effective. For larger areas, mowing or cutting before plants flower can be effective, as long as plants are cut below the first leaf node. Repeat visits are needed for pulling/cutting or mowing multiple times per year to tackle regrowth or new plants (three visits in May/June, July/August and September/October).

Figure 24 Himalayan balsam invading a riverbank.

Chemical control

Glyphosate is an effective treatment if applied sufficiently early (April–June) to prevent flowering. Either foliar application or stem injection can be used, requiring one to three treatments per year until no regrowth occurs.

Disposal

Pulled or cut plants, before they flower, can be dried, as long as any roots do not touch the soil, and then composted or burnt, preferably outside of the riparian buffer. Alternatively, it may be possible to excavate plants and the seed bank, and bury these at least 2 m deep on the adjacent land. Plant material can also be disposed of as controlled waste at a suitably licenced waste disposal facility using an appropriately licenced waste carrier.

Japanese knotweed

Detailed guidance on controlling Japanese knotweed can be found at www.gov.uk/guidance/prevent-japanese-knotweed-from-spreading.

Japanese knotweeds (including *Fallopia japonica* and *Fallopia sachalinensis*) are rapidly growing INNS (Figure 25). Their stems dieback in winter and new shoots are produced from the base the following spring. The underground rhizome can extend 7 m from the parent plant to a depth of 3 m in the soil. Plants grow very quickly, up to 20 cm per day, and can propagate from very small pieces of rhizome.

Japanese knotweed is highly resilient and spreads vegetatively (as opposed to seeds from flowers) through disturbance to roots, disposed waste and contaminated soil, including through fragments of rhizomes and cut stems being washed downstream in watercourses. Once an eradication is complete it is recommended that monitoring of the site is continued until two full seasons have passed without regrowth. It should be noted that regrowth of the plant following herbicide treatment can look different to normal plant growth (e.g. much smaller and straggly). The removal of rhizomes, soil and other material containing Japanese knotweed needs to be treated as controlled waste and either burnt on site or disposed of in a licensed landfill site.

Figure 25 Japanese knotweed in flower.

Mechanical control

Hand pulling and cutting are not considered to be effective at controlling plants. Japanese knotweed should not be strimmed or flailed as this will spread the plants and make the situation worse.

Chemical control

Currently the only effective treatment is glyphosate application for at least 3–5 years. The options are:

- Biannual foliar spray – half of the maximum permitted application rate applied twice per year (first: June–July; second: August–October) is the most effective technique, followed closely by stem injection.
- Stem injection – using the maximum permitted stump treatment application rate applied once a year (August–October).
- Annual foliar spray – using the maximum permitted application rate applied once per year (August–October).

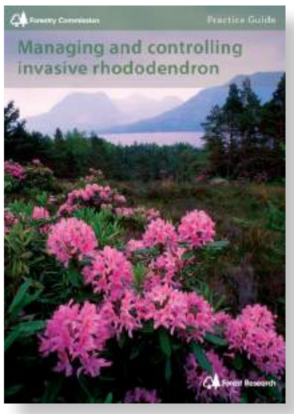
One drawback to stem injection is that the amount of herbicide used is much higher (15-fold) than foliar application, although it is more selective in terms of impact, therefore more suitable for sensitive sites. One annual foliar application is much less effort than a biannual foliar application and is only slightly less effective in terms of results.

Disposal

Plant material and contaminated soil can:

- be buried on the adjacent land close to the site it came from (at least 2 m deep with geotextile seal or at least 5 m deep without);
- be moved to a lined and bunded area on the adjacent land for long-term (3–5 years) treatment with herbicide (if it needs to be removed quickly);
- be sent off site as controlled waste to a suitably licenced waste disposal facility using an appropriately licenced waste carrier;
- have their stems cut above the crown and the leaves can be dried out on a hard surface/ plastic sheet and burnt to ash on site (provided the material cannot be blown or washed away while it dries out or is burnt).

Rhododendron



Rhododendron *(Rhododendron ponticum)* is an invasive non-native evergreen shrub species that favours moist acid soils, where it can dominate to form a dense thicket. It is also a natural host to the pathogens *Phytophthora ramorum* and *Phytophthora kernoviae*, both of which can kill native trees.

Rhododendron spreads by seeds (which generally last one year) and layering of buried stems. Infected rhododendron, and ideally all rhododendron in areas affected by *Phytophthora*, should be destroyed. All rhododendron plant material (foliage, stems and roots) arising from clearance operations suspected to be infected by *Phytophthora* should be removed and destroyed.

Detailed advice on the recommended control method for different types and size of rhododendron can be found in country guidance and/or UKFS Practice Guide, *Managing and controlling invasive rhododendron*. Plants take up to five years before they start to flower, so when planning an eradication, it is recommended that flowering is prevented where possible, by controlling mature plants first and then tackling seedlings/immature plants afterwards. Once the eradication is complete it is recommended that the site is surveyed annually until two full seasons have passed without regrowth, after which there should be visits once every two years, for a further six years.

Mechanical control

The widely used mechanical flails and winches (to pull stumps) are not appropriate within the riparian buffer as they will cause too much soil disturbance and damage, including sediment pollution. Hand pull or dig up small seedlings or uproot medium to large plants. For medium- to large-sized shrubs, hand cutting by chainsaw followed by cut stump treatment with herbicide is recommended. Rhododendron stumps re-sprout vigorously after cutting and can flower and set seed again within two years.

Chemical control

Small trees and young bushes (<1.3 m high) are susceptible to foliar applications (glyphosate with top film or mixture B) between March and October; one to two applications can control small established shrubs. For isolated larger bushes, stem treatment can be very effective (up to 99% kill from a single treatment), with minimal investment in tools and training. A small amount of herbicide is applied into a hole created by drilling into the woody stem. Ground disturbance is minimal; there is little damage to non-target plant species and there is low risk to animals. Dense stands require cutting to provide access, followed by treatment of cut stumps with glyphosate, which is effective all year (optimal in autumn); one application is usually adequate to kill the plant. However, it is necessary to plan for subsequent follow-up treatments of foliar sprays or stem injections to control regrowth.

Disposal

It is preferable that material is disposed of at a nearby site on the adjacent land for environmental reasons and to reduce the potential spread of *Phytophthora*. Green vegetation, rhizomes and seeds can be stockpiled, dried and burned, while woody material can be chipped and used as mulch. Alternatively, the material can be transferred by a registered waste carrier to a suitably licenced waste disposal facility, in accordance with waste regulations.

Monitoring

Monitoring will help to measure progress towards meeting management objectives for the riparian buffer area. Some monitoring will be a one-off exercise but it is more likely to comprise repeated site surveys, at an appropriate frequency and season, for the component aspect(s) involved. Targets can be set, informed by this guidance, as can relevant actions when progress is slow or absent. Certain key aspects should be considered for monitoring.

For riparian woodland within existing forests:

- the growth and establishment of the desired mix of trees, shrubs and ground vegetation;
- the general level of shade, particularly over the water surface;
- tree and shrub encroachment onto open habitats or other protected open features;
- the level and pattern of conifer regeneration;
- the presence and spread of any invasive non-native species;
- the presence and spread of any tree diseases, particularly *Phytophthora* in common alder;
- whether forest and road drains have been disconnected from the watercourse and stopped back at the edge of the riparian buffer area or cut off by a replacement drainage system;
- the stability of bankside trees and the presence of upturned bankside root plates;
- the extent and impact of any bankside erosion or gully development;
- the presence of any solid dams within watercourses formed from brash and deposited sediment forming a barrier to fish movement;
- the amount and relative mobility of logs/trees within watercourses, especially upstream of bridges and culverts vulnerable to blockage and causing local flooding;
- the condition of any riparian fencing, water gates, forest road culverts and bridges, including the extent of trapped woody debris and general litter;
- whether all plastic vole guards and tree shelters have been removed and considered for recycling;
- where beavers are present, the extent of beaver dams, tree felling and impacts on neighbouring land and land use.

For new planting of riparian woodland:

- the growth and establishment of the desired mix and structure of trees, shrubs and ground vegetation;
- the general level of developing shade, particularly over the water surface;
- losses of planted trees due to flooding or washout;
- the presence and spread of any invasive non-native species;
- the presence and spread of any tree diseases, particularly *Phytophthora* in common alder;
- whether all plastic vole guards and tree shelters have been removed and considered for recycling;
- the extent and depth of any deposited sediment and whether sediment deposits straddle the width of the buffer and reach the watercourse;
- the condition of riparian fencing and whether this continues to exclude livestock;
- the growth and condition of the riparian woodland;
- to determine when riparian woodland buffer areas become saturated with pollutants and harvesting is required to maintain pollutant uptake and removal.

Further reading and useful sources of information

Forestry Authority publications

Requirements and guidance

The UK Forestry Standard and its suite of supporting guidance is available from the Forest Research website at www.forestresearch.gov.uk/ukfs

- The UK Forestry Standard (FCFC001)
- The management of semi-natural woodlands: 8. Wet woodlands (FCPG08)
- Managing and controlling invasive rhododendron (FCPG017)
- Managing forests in acid sensitive water catchments (FCPG023)
- Managing open habitats in upland forests (FCPG24)
- Managing forest operations to protect the water environment (FCPG025)
- Designing and managing forests and woodlands to reduce flood risk (FCPG027)
- An Ecological Site Classification for Forestry in Great Britain (FCBU124)

Research

Forestry Commission and Forest Research publications are available from the online publications catalogue at www.forestresearch.gov.uk/publications

- Water use by trees (FCIN065)
- Forestry and surface water acidification (FCRN016)
- Ecosystem services and forest management (FCRN020)

Other publications

External guidance and codes of practice

- Know the Rules Booklet (Forestry & Water Scotland) – https://www.confor.org.uk/media/3513197/know-the-rules-booklet-2nd-edition-jan-2023.pdf
- Keeping Rivers Cool (Woodland Trust) – https://www.woodlandtrust.org.uk/publications/2016/02/keeping-rivers-cool/
- Good Practice Guides (e.g. on bank protection, river crossings, engineering, sediment management, construction methods and riparian vegetation management) (SEPA) – https://www.sepa.org.uk/regulations/water/engineering/engineering-guidance/
- Guidelines for decision-makers, forest managers and landowners on forested water retention areas (FORWARA)
- Assessing the potential hazards of using leaky woody structures for natural flood management: Natural Flood Management Programme: Assessing the risk (ADEPT) – https://catchmentbasedapproach.org/learn/natural-flood-management-programme-assessing-the-risk/
- Surface water alterations handbook (Department of Agriculture, Environment and Rural Affairs) – https://www.daera-ni.gov.uk/publications/surface-water-alterations-handbook
- License to manage and control invasive non-native species – www.gov.uk/government/publications/invasive-alien-species-licence-to-manage-and-control-them-ias-a02
- Northern Ireland Priority Habitat Guide: Wet woodland – www.daera-ni.gov.uk/publications/habitat-guide-wet-woodland

- Codes of practice for using plant protection products:
  - England and Wales (Health and Safety Executive)
  - Scotland (Scottish Government)
  - Northern Ireland (Department of Agriculture, Environment and Rural Affairs)

Reports and information sheets

- Improving the benefits from watercourse field margins using 3-D buffers (Environment Agency 2020) – https://www.gov.uk/government/publications/3d-buffer-strips-designed-to-deliver-more-for-the-environment
- Assessing the effectiveness of woodland creation for reducing agricultural diffuse pollution (Short-Term Scientific Mission Report, COST Action 15206) – https://cdn.forestresearch.gov.uk/2022/02/fr_pesfor_stsm_nacho.pdf
- Riverwoods for Scotland Report on Scientific Evidence (Riverwoods Science Group 2022) – www.riverwoods.org.uk/resource/riverwoods-evidence-review/
- Buffer design and placement (Centre of Expertise for Waters (CREW), Scotland) – www.crew.ac.uk/sites/www.crew.ac.uk/files/publication/CRW2020_03_Buffer_Design_Placement_FINAL.pdf
- Establishing robust species mixtures (Kerr, G., Haufe, J., Stokes, V. and Mason, B. (2020). Quarterly Journal of Forestry, 114 (3), 164–170.)

Websites

UK forestry authorities

- England: Forestry Commission – www.gov.uk/government/organisations/forestry-commission
- Scotland: Scottish Forestry – www.forestry.gov.scot
- Wales: Natural Resources Wales – www.naturalresourceswales.gov.uk
- Northern Ireland: Forest Service – www.daera-ni.gov.uk/forestry

Flooding authorities (most relevant for dealing with riparian woodland and flooding matters)

- England:
  - Environment Agency – www.environment-agency.gov.uk
  - Lead Local Flood Authorities – www.local.gov.uk

- Scotland:
  - Scottish Environment Protection Agency – www.sepa.org.uk

- Wales:
  - Natural Resources Wales – www.naturalresourceswales.gov.uk
  - Lead Local Flood Authorities – www.gov.wales/find-your-local-authority

- Northern Ireland:
  - Department for Infrastructure (Rivers) – www.infrastructure-ni.gov.uk

Other useful websites

- UK nature conservation body: Joint Nature Conservation Committee (JNCC) – jncc.defra.gov.uk
- GB Non-Native Species Secretariat – www.nonnativespecies.org
- Invasive Species Northern Ireland – www.invasivespeciesni.co.uk
- The location of designated sites, priority habitats and protected species:
  - in England and Wales – www.magic.gov.uk
  - in Scotland – www.nature.scot/professional-advice/protected-areas-and-species/protected-species
  - in Northern Ireland – www.daera-ni.gov.uk/services/searching-protected-areas

Appendix 1: National Vegetation Classification

The NVC has described 18 woodland and seven scrub communities in Great Britain, including seven types of wet woodland. The most common tree and shrub species for each woodland type are shown in Table A1. The NVC can be used to predict the type of woodland that is expected to occur naturally, and therefore is most ecologically suited to a site, which can help in selecting the most appropriate species to plant in the riparian zone. W6 and W7 are typical riparian woodland communities closely associated with flowing water; W3 and W4 are associated with flushed sites, which often drain and may be in close proximity to a watercourse; whereas the others are more typical of wetland habitat.

Table A1 The seven types of wet woodland described by the National Vegetation Classification (NVC)

NVC number	Common name	NVC woodland community	Site type
W1	Grey willow with marsh bedstraw	*Salix cinerea – Galium palustre*	Lowland woodland of waterlogged mineral soils of moderate fertility associated with the margin of standing water
W2	Grey willow – downy birch (Alder) with common reed	*Salix cinerea – Betula pubescens – Phragmites australis*	Floodplain woodland associated with alluvial soils and fen peats
W3	Bay willow with bottle sedge	*Salix pentandra – Carex rostrata*	Northern sub-montane woodland of flushed peaty soils
W4	Downy birch with purple moor grass	*Betula pubescens – Molina caerulea*	Woodland of upland acidic flushed peat, basin mires and fens
W5	Alder with tussock sedge	*Alnus glutinosa – Carex paniculata*	Lowland floodplain woodland of base-rich swamps and fen peat
W6	Alder with stinging nettle	*Alnus glutinosa – Urtica dioica*	Widespread lowland riparian woodland of fen peat and rich alluvial soil
W7	Alder – ash with yellow pimpernel	*Alnus glutinosa – Fraxinus excelsior – Lysimachia nemorum*	Hill slope riparian woodland of base-rich flushes with gleyed, mineral soils typical of riparian uplands

The most common tree and shrub species for each woodland type are shown in Table A2. The canopy-dominant species (D) are shown in orange; these are common throughout the geographic range of the NVC community. The combined canopy-dominant species should form 60% of the planting stock. The typical species (T) are shown in dark green; these form a smaller component of the woodland canopy, although they may be locally common in part of the geographic range or within a NVC sub-community. The combined typical canopy species should form 30% of the planting stock. The species shown in grey are minor (M) but typically present components of the woodland canopy. It is desirable that such species are included in woodland creation schemes at low frequency (10%).

The vegetation community of the ground flora can be used to determine the NVC woodland type for a site currently lacking a riparian woodland canopy (Table A3). The species shown in dark green (VC) are frequently found and can be used to indicate which NVC wet woodland type is most likely to develop on the site; the species shown in grey (C) are commonly found in each community.

Wet woodland in Northern Ireland encompasses a range of plant communities that broadly reflect a number of those described in the NVC of Great Britain.

Table A2 Tree and shrub species commonly found in the National Vegetation Classification (NVC) wet woodland communities (from the Forestry Commission Handbook, *Managing native broadleaved woodlands*). Aspen is suitable for high altitude sites in Scotland; field maple only in southern England.

Common name	Scientific name	W1	W2	W3	W4	W5	W6	W7
Field maple	*Acer campestre*						M	
Alder	*Alnus glutinosa*		T		M	D	D	D
Downy birch	*Betula pubescens*	M	D	T	D	T	T	T
Hazel	*Corylus avellana*							T
Hawthorn	*Crataegus monogyna*		M			T	T	T
Ash	*Fraxinus excelsior*		M			D	M	D
Alder buckthorn	*Frangula alnus*					T		
Holly	*Ilex aquifolium*						M	M
Aspen	*Populus tremula*							M
Blackthorn	*Prunus spinosa*						M	
Sessile oak	*Quercus petraea*							T
Grey willow	*Salix cinerea*	D	D	D	D	D	D	T
Crack willow	*Salix fragilis*						T	
Bay willow	*Salix pentandra*			D				
Elder	*Sambucus nigra*						D	M
Rowan	*Sorbus aucuparia*				T			T
Guelder rose	*Viburnum opulus*		M			M		

D, canopy-dominant species (orange); M, minor species (grey); T, typical species (dark green).

Table A3 Common ground flora species indicative of the National Vegetation Classification (NVC) wet woodland communities (from the Forestry Commission Handbook, *Managing native broadleaved woodlands*)

Common name	Scientific name	W1	W2	W3	W4	W5	W6	W7
Water mint	*Mentha aquatica*	VC		C		VC		
Soft rush	*Juncus effusus*	VC	C		C			VC
Common marsh-bedstraw	*Galium palustre*	VC		VC		VC	C	
Meadowsweet	*Filipendula ulmaria*		VC	VC		VC		VC
Cuckoo flower	*Cardamine pratensis*			VC		VC		
Broad buckler fern	*Dryopteris dilatata*				C	VC	C	VC
Common reed	*Phragmites australis*		VC			VC		
Stinging nettle	*Urtica dioica*		C			VC	VC	C
Bramble	*Rubus fruticosus*				C	VC	VC	C
Bottle sedge	*Carex rostrata*			VC				
Water avens	*Geum rivale*			VC				
Marsh valerian	*Valeriana dioica*			VC				
Tufted hair grass	*Deschampsia cespitosa*				C			VC
Marsh marigold	*Caltha palustris*			VC		C		
Wild angelica	*Angelica sylvestris*			VC		C		C
Marsh hawksbeard	*Crepis paludosa*			C				
Water horsetail	*Equisetum fluviatile*			C				
Marsh horsetail	*Equisetum palustre*			C				
Bogbean	*Menyanthes trifoliata*			C				
Marsh cinquefoil	*Potentilla palustris*			C				
Purple moor grass	*Molinia caerulea*				VC			
Marsh pennywort	*Hydrocotyle vulgaris*				C			
Greater birdsfoot trefoil	*Lotus pedunculatus*				C			
Tormentil	*Potentilla erecta*				C			
Marsh violet	*Viola palustris*				C			
Lesser pond sedge	*Carex acutiformis*					VC		
Greater tussock sedge	*Carex paniculata*					VC		
Yellow flag	*Iris pseudacorus*					VC		
Bittersweet	*Solanum dulcamara*					VC	C	
Hemp agrimony	*Eupatorium cannabinum*		C			VC		
False-brome	*Brachypodium sylvaticum*			C		VC		C
Common valerian	*Valeriana officinalis*			C		VC		C
Marsh thistle	*Cirsium palustre*				C	VC		C
Bugle	*Ajuga reptans*					C		
Gypsywort	*Lycopus europaeus*					C		
Yellow loosestrife	*Lysimachia vulgaris*					C		
Purple loosestrife	*Lythrum salicaria*					C		
Hemlock water dropwort	*Oenanthe crocata*					C		
Marsh fern	*Thelypteris palustris*					C		
Cleavers, goosegrass	*Galium aparine*						VC	C
Male-fern	*Dryopteris filix-mas*						C	
Ivy	*Hedera helix*						C	

VC, very common species of the woodland community occurring at frequencies of 60% or more (dark green).
C, common species in some sub-communities of the woodland type (grey).

Glossary

Acidification A continuing loss of acid-neutralising capacity manifested by increasing hydrogen ion concentrations and/or declining alkalinity; the term may be applied to a catchment, water or soils.

Algal bloom A sudden growth of algae in an aquatic ecosystem. Algal blooms occur naturally but may also be induced by nutrient enrichment of waters due to pollution; see Nutrient enrichment.

Approval (pesticides) Chemical products, for which usage and methods of application have been approved by the UK Chemicals Regulation Division (of Health and Safety Executive).

Beaver deceivers A pipe installed within a beaver dam to maintain river flow and lower the water level above the dam. The pipe is protected at both ends by wire caging to prevent blocking by beavers.

Brash The residue of branches, leaves and tops of trees, sometimes called 'lop and top', usually left on site following harvesting.

Buffer area An area of land that protects the watercourse or heritage feature from activities on the adjacent land, such as by intercepting polluted run-off. The buffer area will usually include the riparian zone and may extend into adjacent land. For heritage features, the buffer area will normally be an unplanted area maintained as open ground.

Bunded area An area of land bordered by a constructed embankment that is designed to prevent the release of stored materials or liquids.

Catchment The area of land from which precipitation drains to a defined point in a river system, or to a lake, reservoir or spring.

Compaction The compression of soil leading to reduced pore space, usually due to the weight of heavy machinery. Compacted soils become less able to absorb and transmit rainfall, thus increasing run-off and erosion.

Controlled activities Activities that affect the water environment as defined in The Water Environment (Controlled Activities) (Scotland) Regulations 2005. These include discharges and disposal to land, abstractions from wetlands, surface waters and groundwaters, impoundments such as dams and weirs, as well as engineering works on inland waters and wetlands.

Coppicing A traditional method of woodland management involving the periodic cutting back to ground level of suitable species of trees or shrubs to stimulate regrowth and generate wood products.

Cultivation Any method of soil disturbance to aid the establishment of trees.

Denitrification The conversion of nitrate to nitrite and nitrite to nitrogen leading to the loss of nitrogen from the biosphere. These reactions are carried out by anaerobic soil bacteria.

Diffuse pollution Pollution arising from land-use activities (urban and rural) that are dispersed across a catchment. These are distinct from 'point' sources of pollution associated with discharges of industrial wastes, municipal sewage and deep mine or farm effluent.

Erosion The wearing away of the land surface by rain, wind, ice or other natural or anthropogenic agents that abrade, detach and remove geological parent material or soil from one point on the Earth's surface and deposit it elsewhere.

Establishment (period) The formative period which ends after young trees are of sufficient size so that, given adequate protection, they are likely to survive as woodland at the required stocking density.

Eutrophication See Nutrient enrichment.

Fish-spawning gravels Sorted, clean gravel patches (within watercourses) of a size appropriate for egg laying by fish.

Flushes Areas of wet ground formed by groundwater seepage.

Good status (water) Meeting certain standards for the ecology, chemistry and quantity of water. Applies to four assessments of the condition of surface water and groundwater under the Water Framework Directive. There are five classes of ecological status, the others being high, moderate, poor and bad.

Groundwater All water that is below the surface of the ground in the saturation zone and in direct contact with the ground or subsoil. This zone is commonly referred to as an aquifer, which is a subsurface layer or layers of rock or other geological strata of sufficient porosity and permeability to allow a significant flow of groundwater or the abstraction of significant quantities of groundwater.

Infiltration The entry of water into the soil.

Invasive species Any animal or plant that has the ability to spread, causing damage to the environment, the economy, our health or the way we live. Many invasive species are not native or locally native (called invasive non-native species).

Large woody material Pieces of deadwood larger than 10 cm diameter and 1 m length, comprising whole trees, logs, branches and root boles that can accumulate within river systems.

Leaching The removal of soluble elements from one zone in soil to another via water movement in the profile.

Leaky wood(y) dam A leaky barrier usually consisting of logs and branches, occasionally combined with some living vegetation, that naturally forms or can be placed or engineered in river channels, as well as on riverbanks and across floodplains. It acts to slow river flow and temporarily increase flood storage, including by pushing water out-of-bank.

Main river Designated stretches of river in England and Wales where the Environment Agency and Natural Resources Wales have permissive powers for flood defence purposes to construct and maintain defences and to control the actions of others through byelaws and the issuing of consents.

Morphology The spatial diversity of the physical characteristics of a water body and how it changes dynamically over time due to natural and anthropogenic processes. Geomorphology refers to the size and shape of a water body and stream bed sediments; and hydro-morphology refers to the flow regime.

Mounding (hinge and inverted) The process of forming a small mound of soil on which to plant a tree, thus increasing the aerobic zone of soil and root extension. Mounds can be formed by excavators or continuous mounder machines. Hinge mounding involves a scoop of soil being flipped over to leave one edge of the upper surface intact, while inverted mounding completely inverts a scoop of soil and places this back in the excavated hole.

Mulch mat A piece of material that is used to cover the soil around newly planted shrubs and trees to suppress the growth of weeds and retain soil moisture.

Native species Species that have arrived and inhabited an area naturally, without deliberate assistance by humans. For trees and shrubs in the UK, this is usually taken to mean those present after post-glacial recolonisation and before historical times. Some species are only native in particular regions. Differences in characteristics and adaptation to conditions occur more locally, hence 'locally native'.

Natural regeneration or colonisation Plants growing on a site as a result of natural seedfall or suckering. Regeneration refers to sites from which trees have been removed, while colonisation refers to previously non-woodland sites. The term is also used to describe the silvicultural practices used to encourage natural seeding and establishment.

Nitrate leaching The removal of nitrate in solution from the soil via water movement, with the potential to contaminate surface water and groundwater.

Nitrification The biological oxidation of ammonium to nitrite and nitrite to nitrate by soil bacteria and fungi.

Nutrient enrichment (eutrophication) Excessive richness of nutrients in waters or soils that results in adverse effects on the diversity of the biological system, the quality of the water and the uses to which the water may be put.

Ordinary watercourse A watercourse that does not form part of a main river in England and Wales.

Pesticide Any substance, preparation or organism prepared or used, among other uses, to protect plants or wood or other plant products from harmful organisms, to regulate the growth of plants, to give protection against harmful creatures or to render such creatures harmless.

pH A logarithmic index for the hydrogen ion concentration in an aqueous solution, used as a measure of acidity. A pH <7 is considered to be acidic and one >7 alkaline.

Pollarding A traditional method of pruning trees and shrubs to restrict height growth. This can be used to manage the level of shade and produce a crop of branches for harvesting in subsequent years.

Protected habitat or species Habitats or species protected by law including UK and country wildlife; countryside and conservation legislation provides protection for special sites and listed species.

Redd nest of spawning fish. Typically pale depressions or mounds on riffles and gravel bars in clean, fast flowing water. Fast currents are necessary to maintain sufficient oxygen supply to the eggs in the interstitial spaces within the gravel.

Riparian buffer area An area of land that protects the watercourse from activities on the adjacent land, such as by intercepting polluted run-off. The buffer area will usually include the riparian zone and may extend into adjacent land.

Riparian woodlands Those relating to, or situated adjacent to, a watercourse or water body.

Riparian zone An area in which the terrestrial and freshwater ecosystems interact. The riparian zone is a dynamic environment that naturally supports a mosaic of different habitats, of which woodlands are an important and integral component.

Seepage Water issuing from the ground in the form of flushes or springs.

Shrinkable soils Clay-rich soils that shrink in dry conditions and often become hard and crack; after rain they absorb water and swell to become heavy and sticky.

Siltation Deposition of waterborne, mainly soil-derived, particles within a watercourse, other body of water, or wetland.

Statutory bodies The authorities responsible for nature conservation (Natural England, NatureScot, Natural Resources Wales and Northern Ireland Environment Agency); environmental protection (Environment Agency in England, Scottish Environment Protection Agency, Natural Resources Wales and Northern Ireland Environment Agency); and the historic environment (Historic England, Historic Environment Scotland, CADW (historic environment service of the Welsh Government) and Northern Ireland Environment Agency).

Thinning The removal of a proportion of trees in a forest after canopy closure to promote growth and greater value in the remaining trees.

Water body The basic water management unit defined under the Water Framework Directive for which environmental objectives are set. Water bodies can be parts of rivers, lakes and estuaries, stretches of coastal water or distinct volumes of groundwater.

Watercourse Any natural or man-made channel through which water flows continuously or intermittently.

Wetlands Transitional areas between wet and dry environments, ranging from permanently or intermittently wet land to shallow water and water margins, and including marshes, swamps and bogs and the intertidal zone. When applied to surface waters, it is generally restricted to water shallow enough to allow the growth of rooted plants.

Wet woodland priority habitat Woodland that occurs on wet soils in a variety of situations such as flushed slopes, wet hollows, valley floors and the riparian zone. Wet woodland is widespread in both upland and lowland areas. The most common tree species are willows, downy birch and alder. The epiphytic bryophyte and lichen assemblages on trees, deadwood and rocks can be very rich, especially in the west.

Riparian woodlands are critical to the natural functioning of freshwater ecosystems and form an important habitat in their own right. The interaction between running water, tree roots and fallen wood creates the complex and dynamic aquatic and wetland habitat mosaic needed for characteristic plants and animals to thrive. Riparian trees and woodland are also increasingly valued for providing a range of environmental services, including slowing flood flows, improving water quality and cooling water temperature. Much of our riparian woodland has been lost due to clearance for development and agriculture, with what remains often highly fragmented. There is an urgent need to restore and expand riparian woodland both within existing forested areas and as part of new woodland creation schemes, with the goal of creating a fully functioning dynamic linear network of riparian vegetation of variable tree cover. Doing so will contribute to efforts in adapting to climate change and addressing the biodiversity crisis. This Practice Guide provides advice to forest and woodland owners, managers and planners on creating, designing and managing riparian woodland to protect and enhance riparian and aquatic habitats, in line with the UK Forestry Standard Requirements and Guidelines on Forests and Water.

£12.00

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