Freshwater habitats 9

Tables

Definition and location of freshwater habitats in the uplands

9.1 Definition of freshwater habitats in the uplands

Fresh water has a salinity content of less than 0.5% (McLusky 1994). Freshwater habitats include truly aquatic habitats, ie areas of standing and running water, and the wetland areas associated with them, ie where water is near, at, or above the level of the land (Smith 1979), such as marginal and inundation areas, swamps and fens, bogs and mires, and wet woodland. These areas may be semi-natural in origin, heavily man-modified, or created as a result of man's activities.

This chapter will focus upon the true aquatic habitats as well as swamps and fens. This includes lakes, reservoirs, tarns, ponds, rivers and streams, and their surrounding wetlands. Marginal and inundation grassland communities are discussed in Chapter 7, bogs and mires are discussed in Chapter 6, and wet woodland habitats are discussed in Chapter 8.

Freshwater systems contain a range of habitats. For example, a lake contains sheltered bays, wave-washed shores, and depth zones from shallow areas to deep water. Rivers may contain mid-channel islands, side and point bars, and meanders.

Truly aquatic habitats can be classified according to water movement and nutrient content. In lotic (flowing water) systems, currents are induced by gravity, and tend to be constant in direction. By contrast, the current in lentic (standing water) systems results from wind action and may vary in direction and velocity (Ratcliffe 1977).

Nutrient levels, particularly the presence of nitrogen, phosphorus, and calcium carbonate (alkalinity), dictate the character of freshwater habitats. Five categories can be recognised defined broadly upon nitrogen and phosphorus levels, ranging from dystrophic and oligotrophic systems poor in nutrients, through mesotrophic, to eutrophic and hypertrophic systems high in nutrients (see Table 9.1 and 9.2). Sites with high concentrations of calcium carbonate (defined as greater than 100 mg/l) are called marl sites.

Many other factors also influence the distribution of aquatic organisms. For plants, substrate has an important role. This includes both the structure and nutrient status of the substrate. Where the nutrient status of the substrate differs from that of the water it is more likely that the over-riding influence on the floral community will be exerted by the soil chemistry (Holmes & Newbold 1984).

Water depth and permanency affect the type of vegetation communities found. Some plants characteristically grow in water which persists throughout the year and are true aquatic species (Preston & Croft 1997). The entire plant may be submerged or may float on the water surface, or the basal parts may be rooted in water but send out aerial leaves and inflorescences. Some aquatic plants are adapted to life in the boundary between the land and the water, where changes in water level are frequent.

Table 9.1 Classification of different freshwater types according to alkalinity

	Alkalinity		
	Milligrams per litre of calcium carbonate (mg l^{-1} Ca CO_3)	Milliequivalents per litre (meq l^{-1})	pH
Dystrophic	0-2	(0-0.04)	<6
Oligotrophic	0-10	(0-0.2)	6-7
Mesotrophic	10-30	(0.2-0.6)	*c.* 7
Eutrophic	>30	(>0.6)	>7
Marl	>100	(>2.0)	>7.4

Source: Ratcliffe 1977

Table 9.2 Classification of different standing freshwater types according to nitrogen (N) and phosphorous (P) content

	Total P	Inorganic N
	Milligrams per litre (mg l^{-1})	Milligrams per litre (mg l^{-1})
Ultra-oligotrophic	<0.005	<0.02
Oligo-mesotrophic	0.005-0.01	0.2-0.4
Meso-eutrophic	0.01-0.03	0.3-0.65
Eu-polytrophic	0.03-0.1	0.5-1.5
Polytrophic	>0.1	>1.5

Source: Vollenweider 1968

9.2 Location and extent of freshwater habitats in the uplands

Freshwater and wetland habitats are widely distributed throughout the uplands of England. Their occurrence reflects the topography and geology of the area as well as annual precipitation levels. For example in the Cumbrian Fells and Dales, standing waters account for around 2%of the total land area, while the mean area of standing waters ranges from 0.5 km^2 to >1 km^2 (Smith & Lyle 1979). The frequency of streams per 100 km^2 is highest in the south west of England with between 5-7.5 per 100 km^2 (Smith & Lyle 1979).

Habitats and species of fresh water in the uplands

9.3 Why upland freshwater habitats are important

Most natural lakes of glacial origin in Britain are classified as oligotrophic waters (Ratcliffe 1977). They are found in areas where the underlying rocks are resistant to weathering. Such areas are most often associated with upland and mountain areas. Scotland has some of the best examples of oligotrophic freshwater habitats in Britain as a whole, but England also contains examples. Due to their low nutrient status, oligotrophic systems are particularly vulnerable to change caused by nutrient enrichment and acidification. As many have been enriched, those remaining are valued as examples of this habitat type.

Oligotrophic waters support a characteristic suite of plant and animal communities, including several rare and scarce species. Most of these species are adapted to the low nutrient status of these systems and any change in this status is likely to lead to their loss.

Mesotrophic and eutrophic waters are less well represented in upland areas, mainly because the geology of these areas is predominantly nutrient poor. Where they are present they are often confined to the valley bottoms. Marl sites are scarce in the UK and in the uplands are confined to limestone areas. The most notable marl lake within England's upland Natural Areas is Malham Tarn, the highest marl lake in the UK. Mesotrophic, eutrophic and marl systems all support their own characteristic flora and fauna.

River systems and other wetland habitats in the uplands similarly support characteristic, rare and scarce plant and animal communities and species which are unable to survive in any other conditions.

9.4 Habitats and species of freshwater in the uplands, their nature conservation status and distribution

9.4.1 Vascular plants

Freshwater vascular plant species of nature conservation significance in upland Natural Areas of England are shown in Table 9.3, with their nature conservation status and distribution in upland Natural Areas (Preston & Croft 1997; Stewart, Pearman & Preston 1994). Two upland, freshwater, aquatic macrophytes, floating water plantain *Luronium natans* and slender naiad *Najas flexilis*, are recognised as threatened throughout their European range and in need of special protection. Pillwort *Pilularia globulifera* is an aquatic fern species which is more common in Britain than the rest of Europe. It is normally associated with water bodies at low altitude but is also found in upland Natural Areas.

Aquatic plant species have traditionally been overlooked by botanists and many species are under recorded. They often have specific habitat requirements and their distribution mirrors that of the distribution of suitable aquatic habitats. For example, true aquatic plants are restricted to open or running water and other important factors include water movement, alkalinity, nutrient levels, substrate and depth (Pearsall 1920). The ability to reach new aquatic systems is the main limiting factor.

Some plant species are very closely associated with particular nutrient levels. For example, quillwort *Isoetes lacustris* is only found associated with oligotrophic waters and consequently has a mainly north and west distribution. Other species are more catholic in their requirements and may be found in a range of aquatic habitats eg floating leaved pondweed *Potamogeton natans.*

As part of the UK Biodiversity Action Plan, Species Action Plans have been prepared for priority freshwater species to ensure their protection (Taylor 1994; UK Biodiversity Group 1998; UK Steering Group 1995).

9.4.2 Bryophytes and lichens

Mosses and liverworts make up the bulk of the vegetation of upland and rocky rivers, which do not tend to support the range or quantity of aquatic macrophytes found in more nutrient-rich, lowland situations. In addition, they can be abundant in the wet or damp conditions around freshwater habitats. Nationally rare and scarce freshwater bryophytes and lichens in the English uplands are identified in Table 9.4, along with their nature conservation status and distribution.

9.4.3 Plant communities

The vegetation of upland freshwater areas varies between different habitats. Truly aquatic habitats may be characterised by the presence of algae, floating vegetation, submerged vegetation, marginal or emergent vegetation. Swamp and fen habitats may be characterised by a range of grassland communities, and reed or rush dominated vegetation. The communities of wet grassland, mires, bogs and woodlands are described elsewhere in this handbook.

The National Vegetation Classification (NVC) has been designed as a mechanism to describe all vegetation communities, including the vegetation of true aquatic habitats and swamp and fen habitats (Rodwell 1995). There is some caution amongst aquatic botanists concerning the adequacy of the data set which was used as the basis for the aquatic chapter. Independently of the NVC project two systems were developed for the classification of the vegetation communities of standing and running waters (Holmes 1983; Holmes, Boon & Rowell 1998; Palmer 1989; Palmer, Bell & Butterfield 1992). These systems form the basis of SSSI selection and for this reason they are used here. The NVC is used to describe the vegetation of swamp and fen habitats.

The vegetation communities of lentic, lotic, and swamp and fen habitats present in upland areas of England are shown in Tables 9.5, 9.6 and 9.7. A range of these habitats are listed on Annex 1 of the Habitats Directive, including oligotrophic and marl lakes, and “floating vegetation of *Ranunculus* of plain and submountainous rivers” .

Standing waters

The classification for standing waters relies on the macrophyte vegetation and consists of 10 types, ranging from dystrophic, through oligotrophic, mesotrophic and brackish, to eutrophic (Palmer 1989; Palmer, Bell & Butterfield 1992). In general oligotrophic waters (Types 1-3) have a predominantly north and west distribution, and are found in areas where the underlying geology is base-poor. They are the commonest type to be found in the uplands of England. Type 2 communities are common in the upland tarns of the Lake District, whilst Type 3 and Type 5 are found in a number of the larger lakes in this region. Types 8, 9 and 10, ie those with high alkalinity and pH, have a more restricted distribution in the uplands and are more typical of lowland areas, eg the meres of Shropshire, Cheshire and Staffordshire. Type 9 communities within the uplands are restricted to the Cumbrian Fells and Dales.

Running waters

The classification system for British rivers is based on their aquatic plant communities (Holmes 1983; Holmes, Boon & Rowell 1998). There are four broad groups (A-D) representing an environmental gradient from lowland eutrophic rivers to those that are essentially upland, torrential and oligotrophic.

These four groups are divided into 10 river community types. Those relevant to the uplands are described below and shown in Table 9.6.

Upland rivers are generally distributed towards the western side of the country, reflecting areas of higher rainfall and topography. The nature of vegetation communities changes along their length, reflecting changes in slope, geology and substrate. Thus a single river may be classified as several types along its length from source to mouth.

In the English uplands river types 6, 7, 8 and 10 are most frequent. The communities associated with Type 6 have variable characteristics but a close affinity with areas of sandstone and hard limestone. They occur predominantly in the north and west of the country, and tend to form the downstream reaches of rivers which rise at moderate to high altitudes. Type 7 rivers generally have a neutral or mesotrophic status and examples can be found in the north Pennines and in south west England on Exmoor. Like Type 6 rivers they tend to be found in areas which receive high rainfall. Type 8 communities are often associated with rivers that flow through upland bogs and fens. They occur most frequently in Scotland and Wales but examples can be found in the Lake District, the Pennines and south west England. The communities of Type 9 and 10 rivers are truly oligotrophic, occurring on neutral or slightly acidic geology. Most sites occur at high altitudes and generally they have a more northerly and westerly distribution. Type 2 rivers occur infrequently in upland areas, and are associated with clay substrates. An example occurs in the central Marches on the Welsh border.

Swamp and fen communities

The distribution of swamp and tall-herb fen communities in the upland Natural Areas of England are shown in Table 9.7. As with the standing water types, fen and swamp communities tend to be distributed according to trophic status. The *Carex rostrata* swamp (S9) and the *Carex rostrata-Potentilla palustris* fen (S27) communities are largely restricted to oligotrophic and mesotrophic waters, while the *Sparganium erectum* swamp (S14) and the *Phalaris arundinacea* fen is more commonly found in mesotrophic to eutrophic waters. Certain communities have specific habitat requirements, which are only met in a few localities. The *Cladium mariscus* swamp and sedge-beds (S2) are restricted to areas with a calcareous influence. Examples of this community in upland areas are restricted to the Carboniferous Limestone of the Cumbria Fells and Dales.

9.4.4 Birds

Birds use freshwater habitats for feeding, breeding and roosting. The species present and the activities occurring at any one location vary seasonally. For example, certain species are found along rivers during the breeding season, while others roost around lakes in the winter.

A variety of species are regularly associated with upland freshwater habitats in England, although only the dipper *Cinclus cinclus* is confined largely to the uplands. Other species include wigeon *Anas penelope*, teal *A. crecca*, goosander *Mergus merganser*, osprey *Pandion haliaetus*, common sandpiper *Actitis hypoleucos*, black-headed gull *Larus ridibundus*, common gull *Larus canus* and grey wagtail *Motacilla cinerea* (Table 9.8). The adults and young of some birds may forage at the water's edge if it occurs within their territory, eg waders such as oystercatcher *Haematopus ostralegus*, redshank *Tringa totanus* and snipe *Gallinago gallinago*, but these are covered in more detail elsewhere in this handbook. Many more bird species occur on freshwater habitats in the uplands but most are more generally associated with lowland habitats and so are not covered here (see Stillman & Brown 1994 for the identification of breeding bird species associated with the uplands). Examples include kingfisher *Alcedo atthis*, sand martin *Riparia riparia*, yellow wagtail *Motatilla flava*, whooper swan *Cygnus cygnus*, geese and cormorant *Phalacrocorax carbo*.

Only three of the species considered here are regarded as being of nature conservation concern - teal, wigeon and osprey (RSPB 1996). For the former two species this is because of the international importance of their winter populations in Britain. As they winter in the lowlands, especially coastal wetlands, they should not be a particular concern for upland land managers. Ospreys are of concern due to their historical decline and their unfavourable conservation status in Europe. They currently use a few sites in northern England and may become established as a breeding species in due course.

The dipper is a useful indicator of river quality and condition, because it shows a strong correlation with the abundance or availability of large stream invertebrates, such as caddis larvae and mayfly nymphs, on which it feeds. These insects decline or disappear as water quality declines, for example in terms of increased nutrients or suspended solids. They also become less available to dippers as water depth increases. Any factors affecting the numbers, distribution and availability of these prey items are likely also to affect the number and distribution of breeding dippers (Marchant *et al* 1990).

Goosanders are of note because they have substantially increased and spread south from Scotland and into England over the last century (Marchant *et al* 1990). This has brought them into conflict with fishing interests in some areas because they feed on fish.

9.4.5 Invertebrates

A large and varied set of habitats is covered by this chapter and these support a great diversity of invertebrates. Invertebrates are found in all freshwater habitats and many are species of conservation concern because of their rarity or the restricted nature of their distribution.

Larger water bodies, such as pools, tarns and lakes, support aquatic invertebrates including dragonflies, water beetles and pea mussels. Rivers and streams can contain insects such as mayflies, caddis flies and stoneflies. The margins of freshwater habitats and surrounding wet areas support beetles, craneflies, spiders, snails and many other invertebrates. In the majority of water bodies, the margins are the most important parts for invertebrates, including the emergent plants, marginal mud or shallow water (Kirby 1992). Physical features in and around water courses, such as sand, silt and shingle shoals, bars and banks, are also particularly important for invertebrates such as beetles, flies and spiders. Away from water courses and bodies, a very small volume of water or area of wet habitat may provide a breeding site because invertebrates are small.

The greatest diversity of stoneflies and mayflies occurs in clean stony rivers and large streams, making the uplands particularly important for these groups. With the exception of stonefly *Rhabdiopteryx acuminata*, none of those characteristic of upland rivers and streams is nationally scarce.

In still water, caddis flies, some mayflies and water boatmen are often the most frequent species, and include several species restricted to upland locations, such as the boatmen *Callicorixa wollastoni* and

Arctocorisa carinata and the water skater *Gerris costai* in peat pools, and the cased caddis *Apatania muliebris* on stony lakes shores.

Exposed gravels deposited by rivers, especially in their lower reaches where the beds can be large, support a large number of ground beetles and rove beetles rarely found in other situations. A smaller number of flies and spiders are also restricted to this apparently inhospitable habitats.

Invertebrates of freshwater habitats are more than adequately discussed by other publications and this will not be duplicated here (Kirby 1992; RSPB, NRA & RSNC 1994). However, important molluscs and crustaceans are particularly associated with fresh water in the English uplands and these will be covered here. They include the freshwater pearl mussel *Margaritifera margaritifera*, the bivalve *Psidium conventus*, the white-clawed crayfish *Austropotamobius pallipes* and opossum shrimp *Mysis relicta* (Table 9.9).

Unfortunately there has been a dramatic decline in many of the known populations of the freshwater pearl mussel in England to the point where the majority are now considered functionally extinct. However, there are a few populations within Cumbria, Shropshire, North Yorkshire and Northumberland, one or two of which are quite large, which are still considered to be viable. These populations will require special efforts if their long-term conservation is to be achieved.

The increased spread of non-native crayfish species and the associated crayfish plague disease, from the south to the north of England has led to major losses of the once widespread native crayfish due to both the disease itself and competition for food and shelter. Fortunately the upland areas of England remain relatively unaffected by non-natives or plague and are therefore an increasingly important area for the native crayfish. This has been recognised by the designation of a major part of upland England as a no-go area for non-native species under the MAFF Crayfish Order (MAFF 1996a). A number of rivers in Cumbria, the Yorkshire Dales, the North Yorkshire Moors and the Peak District, particularly those which run off limestone, hold strong healthy populations. There are also a number of lakes and reservoirs which contain good populations and these are potentially important refuge sites if plague were to advance farther north. Protection of all these sites is vital if long-term conservation of native crayfish is to be achieved.

9.4.6 Mammals

Mammals associated with upland freshwater habitats in England include otter *Lutra lutra*, water vole *Arvicola terrestris* and water shrew *Neomys fodiens*. Bats are also associated with these habitats because they use them as feeding areas. They include in particular Daubenton's bat *Myotis daubentonii*, but also the whiskered bat *Myotis mystacinus*, Natterer's bat *Myotis nattereri*, noctule *Nyctalus noctula* and pipistrelle *Pipistrellus* spp.

The otter has a localised distribution, and is extinct or endangered over much of mainland Britain and vulnerable elsewhere. However, the species is generally increasing following major losses between the late 1950s and the 1970s. It tends to be more common away from intensive agriculture or industrialised areas. The water vole is still moderately common but also declining. There has been a significant decline in the number of populations over the course of this century. It is widespread and generally more associated with lowlands (usually below an altitude of 50 m), but they have been recorded in head streams in the uplands (up to 660 m). The water shrew is widespread and locally common. The patchy distribution and ephemeral nature of the populations mean that population trends are uncertain but they are possibly declining. Bat populations generally are also declining.

Mink *Mustela vison* have become naturalised along many rivers of the British Isles since their escape from fur farms. They are predators of a wide variety of mammals, birds, fish and invertebrates and their effect on waterfowl and other wildlife is controversial.

9.4.7 Amphibians and reptiles

Amphibians and reptiles particularly associated with upland freshwater habitats include frogs, toads, newts and the grass snake *Natrix natrix*. Adder *Viper aberus* and slow worm *Anguis fragilis* also occur in the uplands, in a variety of habitats, and are covered elsewhere in this handbook.

! Common frog *Rana temporaria*: widespread, locally common.

! Common toad *Bufo bufo*: widespread, locally common.

! Natterjack toad *Bufo calamita*: localised, very limited distribution in uplands (one known fell site, Habitats & Species Directive Annex IV).

! Palmate newt *Triturus helveticus*: widespread, locally common.

! Smooth newt *Triturus vulgaris*: widespread, locally common.

! Great crested newt *Triturus cristatus*: widespread, declining but may be locally abundant, and more often found in lowland habitats (Habitats & Species Directive Annexes II and IV).

! Grass snake *Natrix natrix*: widespread, locally common but more associated with lowland habitats. This is the reptile species most associated with water on account of the notable occurrence of fish and amphibians in its diet.

9.4.8 Fish

Fish species important in nature conservation terms and associated with upland freshwater habitats are shown in Table 9.10. Species associated with upland rivers and streams include salmon *Salmo salar*, brown trout *Salmo trutta*, sea lamprey *Petromyzon marinus*, brook lamprey *Lampetra planeri*, river lamprey *L. fluviatilis* and bullhead *Cottus gobio*. All are widespread throughout the uplands. In addition, twaite *Alosa fallax* and allis shad *A. alosa* are restricted to a small number of estuaries and river systems, along the west coast. Grayling *Thymallus thymallus* are known from a number of locations. It is likely that the populations of grayling have been introduced, and in many cases will be maintained through stocking. In some areas they may be subject to culling where it is perceived that they compete with other salmonids.

Significant species associated with upland lakes and tarns include vendace *Coregonus albula*, schelly *C. lavaretus* and arctic char *Salvelinus alpinus*. Vendace are restricted to two lakes, Bassenthwaite and Derwent Water both within the Lake District. Schelly are restricted to four lakes, Brotherswater, Haweswater, Red Tarn and Ullswater all within the Lake District. Arctic char are also confined to the Lake District but their distribution is more widespread.

A number of the fish species listed above are migratory species. Adults of some species live out at sea and only migrate into freshwater to spawn (anadromous species). The juveniles spend varying amounts of time in freshwater before returning to the sea. Some species, eels *Anguilla anguilla* for example, return to the sea to spawn (catadromous). Other species simply migrate within the river system (non-anadromous). However, salmonids, shad and lampreys all have forms with differing migratory habits which utilise different parts of river systems.

Adult salmon migrate to fresh water between early spring and autumn. The early spring run fish tend to be older fish that have spent several winters at sea, while the late running fish tend to be young fish that have spent only one winter at sea. The extent of their migration through an individual catchment will depend on the location of obstructions as well as the flows at the time of the migration. Spawning occurs between November and January. Eggs are laid in gravel beds and emergent fry quickly develop into parr, which may redistribute themselves in the river. At one to two years old they smolt up and migrate back down to sea.

Brown trout were formerly commonplace in upland waters and are now becoming less common, probably due to the introduction of rainbow trout. There are two forms, migratory sea trout and the non-migratory brown trout. Both forms spawn in upland rivers and streams.

River lamprey migrate into fresh water in spring and if no obstructions occur, adults will migrate up into the headwaters of a river system. Juveniles will remain in fresh water for up to five years. Sea lamprey also migrate but they tend to move only a short way into the river system, and spawn in deep fast-flowing waters in the lower reaches of a river. Interestingly, brook lamprey do not migrate, but remain in fresh water all their life. The only migration which occurs involves the young (ammocoetes) moving downstream from spawning gravels to silt beds and the return movement of developed adults to the spawning gravels.

Little is known about the migration of the allis shad, but it would appear that adults move from the estuary into the lower reaches of rivers during April to August. In contrast twaite shad have been known to migrate long distances up main rivers, but rarely into tributaries.

Many fresh waters, both still and flowing, have been subject to fish introductions in the past and now support species not characteristic of these areas. Pike *Esox lucinus* for example have been introduced into waters where the species did not naturally occur. These 'alien' species can have major impacts on other fish species and / or the general lake or river ecology. This is well illustrated by the introduction of ruffe *Gymnocephalus cernuus* and roach *Rutilus rutilus* into Bassenthwaite. The ruffe, a small predatory fish, probably originally introduced through its use as a live bait, is now known to prey on vendace eggs. Competition and predation from pike, perch *Perca fluviatillis*, roach and other species is probably also very harmful to vendace populations (Maitland 1996).

Another fish problem in fresh waters has been the stocking of rainbow trout *Salmo gairdneri*. Native to the Pacific Coast of North America these have now been widely introduced for their sporting and food value. Within England there are now some rivers with self sustaining populations, ie R. Wye in the Peak

District, while in other rivers small populations are maintained by the regular stocking of hatchery reared fish.

Inappropriate stocking is not confined to new species of native or non-native species. There are also many examples of indiscriminate stocking of salmon and brown trout to enhance natural stock. These have direct implications for the genetic integrity and local adaptation of native stocks, and are now generally not endorsed by the regulatory agency, the Environment Agency, except in extreme conditions where major mitigation schemes are necessary (see Environment Agency 1998b).

9.5 Habitat and management requirements of upland freshwater species

9.5.1 Vascular plants

The management requirements of upland freshwater plant species can be divided into those which relate to the growth form of the plant (eg emergent or submerged) and those which are more species specific. In the case of rare or scarce species, management is carried out to promote growth and encourage re-colonisation of new areas. For invasive species management aims to prevent the spread of new plants and destroy existing growth (see 9.10.7).

The general management requirements for promoting plant growth are (Gardiner 1996):

- maintenance of water quality;
- maintenance of appropriate water levels;
- control rates of sediment erosion and accretion.

Tables 9.14-9.16 provide the habitat and management requirements of selected freshwater plants.

Further information: Maitland & Morgan 1997; Newbold & Mountford 1997; RSPB, NRA & RSNC 1994.

9.5.2 Birds

A high degree of naturalness and good water quality are particularly important elements of freshwater habitats for the birds associated with them. The availability of nesting sites also influences whether birds can live in a particular area. Water levels, flow regimes, and the associated wetland, bank side and other surrounding habitats are also important. Many species feed on invertebrates while others feed on plants or fish. The invertebrates may be associated with the freshwater system or the surrounding habitats, such as grassland. A summary of these habitat and management requirements are shown in Tables 9.17 and 9.18.

9.5.3 Invertebrates

9.5.3 Invertebrates

Guidance on the habitat and management requirements of invertebrates of freshwater wetlands are covered extensively in Kirby (1992) and RSPB, NRA & RSNC (1994) and for this reason are not repeated here. However, two invertebrates, the pearl mussel and white-clawed crayfish are of particular nature conservation concern in upland fresh waters and their requirements are discussed below.

In general terms, the habitat requirements of freshwater pearl mussels and the white-clawed crayfish are similar. They require unpolluted, well oxygenated water, clean gravels for reproducing and a mosaic of habitat features to provide food and shelter. The habitat and management requirements of these species are summarised in Table 9.19.

Pearl mussel

Pearl mussels are associated with clear, cool, fast-flowing unpolluted rivers with soft water, ie water low in calcium and nutrients. Nutrient enrichment (eutrophication) is believed to be the single most important factor to have caused their decline in England.

Mussels tend to favour gravel pockets behind emergent boulders in riffle areas. However, they can also be found in deep pools up to 2 m deep with slow flows. Although habitat preferences are varied, they do prefer stable areas and are also rarely found in fine sediments. Consequently they are often found in linear beds along the line of greatest flow and maximum stability. There also appears to be a preference for areas with shade from overhanging vegetation. The requirements of pearl mussel, and the implications of these for the management of rivers containing pearl mussel are thoroughly reviewed by Oliver & Killeen (1996).

White-clawed crayfish

Crayfish can be found in a variety of rivers and still waters. Their main requirement is for well oxygenated, calcium rich water. Although found in riffles or fast-flowing waters hiding under stones and cobbles, they are most abundant in slower flowing waters where they can also hide up within uncut banks and tree roots.

9.5.4 Mammals

Habitat and management requirements of certain mammals associated with fresh waters are shown in Table 9.20. The quality of the water and the surrounding habitat are particularly important for these species. For example, otters require a range of habitats along the river margin with a good vegetation structure providing cover up to the river edge. Diverse bank side vegetation and associated wetlands are also required by other mammals such as water vole and water shrew.

9.5.5 Amphibians and reptiles

Amphibians are obviously particularly associated with water systems and wetland habitats. The habitat and management requirements of the rarer amphibians, great crested newt and natterjack toad, are shown in Table 9.20. For these and the commoner species, pond, lake and reservoir management is very important. In upland systems, with generally nutrient-poor soils, exposed conditions, high water tables in bogs and grazing pressures, the need to manage water bodies may be less than in lowland situations.

Ideally for amphibians, ponds and the margins of larger water bodies should be unshaded by trees and bushes, at least to the southern side, and there needs to be sufficient open water for egg laying and courtship. There will be cases where water bodies need to be managed to remove invasive plants or accumulated silt and sediment. Plant removal can be by hand or through the use of herbicides, although clearly the impact of the latter on non-target species needs to be considered. Grazing can also be used to remove vegetation and open up water bodies. Silt removal usually requires digging, for example with a JCB. Where management of this nature is required, it is preferable to manage only part of the water body at any one time so that other interests present are not jeopardised.

In areas with amphibians but a shortage of breeding water, new ponds can be created or old ones restored. In some areas, especially those with high water tables, pond creation can be simple, perhaps by reducing water flow or seepage and in others by excavating a hole in the ground. Equally, in quarries where the ground is impermeable collected rain water can form very valuable ponds. Elsewhere, creation of standing water is more difficult and may have undesirable impacts on the hydrology elsewhere. In some cases, the creation of artificially lined ponds may be appropriate. Concrete, plastic or butyl lined and puddled clay ponds (dew ponds) have been used successfully in some areas.

For amphibians it is often better to create a series of small water bodies, each perhaps approximately 100-200 metres squared, rather than a single large pond. Generally these should not be too deep, usually less than one metre, and have shallower margins. This means that any individual pond is less likely to become unsuitable in any year (eg through fish incursion) and means that damage to surrounding areas will be minimised and more easily reversed if necessary. Emergency management, for example deepening ponds in dry years, should be avoided; ponds should not be deepened unless it appears that water tables will be lowered for more than just the occasional dry year. Over-zealous pond deepening has actually caused more problems for natterjack toads, for example, because the habitat subsequently became more suitable for the commoner species of amphibian.

In areas where amphibian populations are being threatened due to acidification, the addition of chalk or quick lime can be considered. The objective is to raise the pH above 5, and for amphibians ideally towards pH 7. Doses between 1 kg per 4 m^2 have been recommended, depending on depth (more for deeper ponds). Pond area is usually calculated on area during the winter months. Timing of application depends on the species being conserved: for the common five species application should be in January or February; for natterjacks lime should be applied in March or early April so that it does not benefit the commoner species. Care needs to be taken when applying lime to avoid damaging other acid-loving species found in these ponds, or in areas where the water may drain or leach. This may mean that in some cases the pH should be raised only a minimal amount or in others that this application is not appropriate. In the latter case, conservation of amphibians may require the creation of artificial ponds. Other features can also be created to enhance habitats for all amphibians, such as log piles on the surrounding land to create hibernation areas.

The common lizard, slow worm, adder and grass snake are often found in damp habitats associated with fresh waters. However, the grass snake is the most aquatic of the reptiles, often swimming and feeding on amphibians. As with most animals of fresh waters, good water quality, a diverse range of surrounding habitats and a plentiful supply of food are important. A summary of its habitat and management requirements is shown in Table 9.20.

Further information: Beebee & Denton 1996; Gent & Gibson 1998.

9.5.6 Fish

Fish require unpolluted, well oxygenated water, clean gravels for spawning and a mosaic of habitat features to provide food and shelter. The habitat and management requirements of fish species of conservation concern in upland freshwater habitats are summarised in Table 9.21.

Bullhead, although widespread throughout river catchments, appear to favour fast-flowing clear shallow water and are particularly abundant in the headwaters of upland streams where they will be found sheltering deep within the river gravels. However, they can also be found lower down the river sheltering in thick weed beds.

All species of lamprey need clean gravels for spawning. The sea and river lamprey, which tend to spawn lower down in a river system, can use large gravels. The smaller brook lamprey, which is found in the upper reaches, appears to prefer small sized gravels in areas where the current is not too strong. Once hatched, the ammocoete larvae of all three species drift downstream and burrow into beds of fine silt or sand, where they remain for five to six years until they mature into adults. Beds located within shaded margins are commonly used but if the amount of fine material is limited cobbles and small stones can be utilised. Although lampreys need silt, they cannot survive in silt with a high organic content since this also tends to have little or no oxygen.

Both salmon and trout require deposits of clean deep gravel in fast-flowing water for spawning. As young salmon and trout develop they require medium-fast riffles and runs where there is plenty of cover in the form of weeds or rocks and an increased supply of food. The water should be cool, clean and oxygenated. Adult salmon and trout need space in deeper water, with plenty of cover in the form of undercut banks, overhanging vegetation, weed or rocks.

Grayling occur mainly in clean, well oxygenated, fast-flowing streams and rivers, but can thrive at oxygen concentrations at which trout would begin to feel uncomfortable.

Allis and twaite shad occur in a small number of estuaries and river systems along the west coast. Little is known about the habitat requirements of shad in fresh water, although French research has shown that both twaite and allis shad can use the same areas for spawning. Twaite shad are known to spawn at night in shallow areas of water near to a deep pool where the fish congregate beforehand.

Vendace and schelly require deep, cool, well oxygenated water and in England occur only in lakes. Oxygen in particular is a key factor. Spawning takes place in littoral gravels and these need to be clean and unsilted. Recent sampling in 1996 and 1997 has shown that many of the areas known to have supported spawning in the past are now covered with fine organic silt rendering them unsuitable for spawning. Arctic char have a reputation of being found only in large, deep, oligotrophic lakes, lying in glaciated basins. Although this is often the case, there are also populations that spawn in shallow, biologically rich habitats in rivers.

Further information: Maitland & Morgan 1997; Newbold & Mountford 1997; RSPB, NRA & RSNC 1994.

Management of upland freshwater habitats

9.6 Conservation objectives for upland freshwater habitats and species

9.6.1 Vascular plants

Conservation objectives for the two internationally important plant species of upland fresh waters, floating water-plantain *Luronium natans* and slender naiad *Najas flexilis,* are given in their Species Action Plans (UK Steering Group 1995). Species Action Plans for other freshwater species have also been produced (UK Biodiversity Group 1998).

9.6.2 Plant communities

General conservation objectives for plant communities of standing waters, running waters and swamp and fen habitats are listed in Tables 9.11-9.13. In many cases the main focus should be to minimise the impacts of routine use and management, for example abstraction or channelisation, upon the conservation interest of a freshwater site. This generally relates to maintaining or restoring the appropriate water quality, water level and rate of sediment erosion and accretion. In cases where aquatic vegetation needs to be managed, it may be to control the dominance by floating leaved species, or to reduce the spread of marginal and emergent communities.

In general, aquatic plant communities require minimal management for nature conservation purposes. Traditionally, management has focused upon either the control of nuisance 'weed' species, and, to a lesser extent, the re-establishment of plant communities following major perturbations (eg eutrophication of the Norfolk Broads). Options to combat eutrophication in certain locations have also been proposed (English Nature 1998b).

Further information: English Nature 1997d; Gardiner 1996.

9.6.3 Wetland habitats

The following objectives have been identified by English Nature for freshwater wetlands in upland Natural Areas (Gardiner 1996):

- Maintain and enhance the current extent, diversity and condition of wetland habitats through appropriate management and subsequent monitoring.

- Meet all the requirements of international treaties relating to wetland conservation, namely the Ramsar convention, Birds Directive and Habitats and Species Directive.

- Restore and enhance the hydrology, water quality and management of wetland sites that are currently considered to be in an unfavourable condition.

- Seek opportunities for habitat creation of wetland habitats.

- Maintain and enhance important populations of wetland plants and animals and carry out appropriate monitoring to determine their status.

Further information: English Nature 1997d; Gardiner 1996.

9.6.4 Animals

Objectives are included below for native crayfish, the freshwater pearl mussel and freshwater fish, as examples of conservation objectives for animals in upland freshwater habitats in England. Those for the former two species have been identified by the UK Biodiversity Action Plan (UK Steering Group 1995) while the objectives for freshwater fish in upland areas have been identified by English Nature.

White-clawed crayfish

- Maintain existing populations through appropriate habitat and water quality management.

- Prevent further spread of non-native species into areas containing native species.

- Develop and apply tools and techniques for eradicating non-native crayfish populations, particularly where they threaten sensitive sites or important populations of native crayfish.

- Support, where feasible and appropriate reintroduction programmes of native crayfish.

Pearl mussel

- Maintain and where possible increase the size of existing populations through appropriate habitat, water quality and land use management.

- Seek to re-establish new populations of this species in at least 10 suitable former areas.

Fish

- Maintain and where appropriate enhance existing populations through appropriate monitoring and subsequent habitat and water quality management.

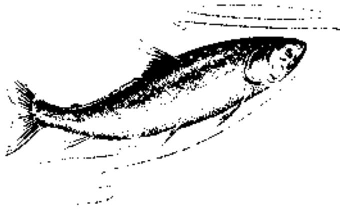
- Meet all the requirements of international commitments, namely the Ramsar Convention and Habitats and Species Directive.

- Seek opportunities for habitat creation.

- Support appropriate translocation programmes for rare and endangered species.

- Resist future stocking of fish unless appropriate to secure long-term conservation status.

9.7 Managing freshwater habitats



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For the majority of freshwater habitats, management is usually only required where human activities have caused a change in the natural conditions, or where particularly vigorous plants start to dominate the vegetation communities. In the following sections the impact of human activities upon freshwater systems is reviewed. Advice on ways to minimise or reverse adverse impacts through management is highlighted. These issues are considered under three headings:

- wider issues, ie those which occur outwith the catchment, but may affect fresh waters (9.8);
- activities which occur within the catchment (9.9);
- direct uses of water bodies and the resulting impacts (9.10).

When managing fresh waters it is essential that the many legal requirements affecting these areas are followed. These are too numerous to cover in this handbook and appropriate publications are available (eg Fry 1997; Gregory 1994; Howarth 1992; Lister 1996; Longworth 1992; Polden & Jackson 1994; Wolf & White 1997). The Environment Agency (formerly the National Rivers Authority) is responsible for the protection of the water environment in England and Wales. The organisation has statutory responsibilities for water resources, pollution control, flood defence, fisheries, conservation, recreation and navigation. It is advisable to contact them prior to initiating new management regimes.

Freshwater habitats are dynamic systems. The quantity and relative proportions of particular species within the communities may change annually depending upon, for example, spring light levels and rainfall. Little is currently known about natural fluctuations in systems making detection of long term trends difficult.

Land use in the uplands, however, has a significant effect on the geomorphological processes occurring in river systems. Increased grazing and deforestation, for example, particularly at the headwaters of a catchment, reduce the water-carrying capacity of the ground. Soil erosion, sediment transport and bank side erosion are then increased, and produce a higher sediment loading of the system. Many of the problems that are being tackled by river management are really only addressing symptoms of problems caused by land management practices in the headwaters of the catchment.

9.8 Wider issues affecting freshwater habitats

9.8.1 Acidification

Acid rain originates from oxides of sulphur and oxides of nitrogen released during the combustion of fossil fuels. Following oxidation and reaction with moisture in the atmosphere acid rain or snow is produced (wet deposition). In areas where there are insufficient base ions in the soil or the water to buffer the acid cations, these cause significant decreases in pH. This is particularly the case in upland areas across England, where the predominant underlying rocks are acidic or resistant to weathering, eg granite, and provide little buffering capacity in the soil or water. Certain vegetation types, in particular coniferous forestry, also tend to exacerbate the problems of acidification by accumulating the pollutants on their foliage.

The pH of freshwater habitats is critical to the plants and animals present. The preferred pH range of many aquatic plants, for example, is around neutral (Table 9.1). Acidification of fresh water is likely to alter plant and animal communities, and could lead to the loss of rare or scarce species where it is particularly severe.

The long-term solution lies in reducing emissions of pollutants to the atmosphere. Liming of adjacent land has been used to counter the impact of acidification, but has uncertain results and is rarely recommended.

Further information: Howells & Dalziel 1992; Ormerod & Buckton 1994.

9.8.2 Climate change

In addition to the predicted increases in temperature (see 2.13.3), climate models also forecast that precipitation will rise. The UK Climate Change Impacts Review Group study (CCIRG 1996) envisages a gradient of warming in the UK from south east to north west, with winter warming ranging from 2° C to 0.8° C by the 2050s and summer warming from 1.8° C to 1.2° C. The study also predicts that annual precipitation will rise by 5% by the 2020s and 10% by the 2050s. Winter precipitation is likely to increase everywhere, whereas summer rainfall is forecast to decrease in the south east and increase in the north west.

The Environment Agency has identified a number of issues relevant to climate change on freshwater systems. These include the reliability of ground water resources and ground water recharge, and changes in wetland and riverine environments, including flow patterns and flood risk, water resources and quality, fish habitats and the aesthetic quality of river corridors. Clearly these issues must be given consideration when developing strategies for managing freshwater habitats in the uplands, with due regard being given to adaptation, mitigation and determination of policy, particularly in relation to other key areas of nature conservation policy.

9.9 Catchment issues affecting freshwater habitats

9.9.1 Agriculture

Agriculture is the principal land use in most upland areas and is a major catchment issue affecting freshwater habitats.

Pastoral

In many upland areas natural water bodies such as streams or tarns are used as drinking water sites for stock. This can result in severe trampling of the banks, leading to erosion of river or stream margins, particularly where banks are steep and prone to collapse. It can lead to increased sedimentation in the water body, which may affect the aquatic flora and fauna. Many aquatic plants, for example, require clear water in order to photosynthesise, and many fish require clean gravels for spawning.

Stock access to riparian sand and shingle banks severely reduces their value in supporting significant invertebrate communities. Cattle may also graze aquatic vegetation (mainly emergent species) where they are able to wade into shallow streams and standing water bodies. Damage to the substratum and increased turbidity can be particularly acute in small ponds where cattle may have access to the entire water body.

Trampling of any water margin can lead to the loss of emergent and edge species. Some plant species, such as lesser water-plantain *Baldellia ranunculoides* and blinks *Montia fontana,* benefit from a low level of trampling and disturbance because it creates openings for colonisation. However, many marginal species will be lost if heavy trampling by cattle continues. This not only destroys the plant communities, but also the habitats used by invertebrates, for example dragonflies and damselflies, which require emergent vegetation. In addition, it removes the cover and food required by other animals such as water voles.

Methods for managing watering areas will vary according to the slope of the bank and surrounding land (Environment Agency 1998c; MAFF 1992a, 1997c & 1999b. Where the slope of the bank is shallow, stock can be allowed open access to the water's edge provided repeated trampling does not result in a 'cliff' rather than a slope. If stream banks are steep throughout the length of the stream, it may be best to fence the entire length, allowing the fence line to pass through the stream itself where there is a bend in its course. The unfenced area can then become the watering area, and although it will become eroded the remaining length of stream is protected. (See also 9.10.8 regarding pastoral land around small ponds and tarns)

The fertiliser and slurry spreading associated with pastoral management can lead to enrichment of water systems and subsequent changes in the flora and fauna. This is particularly so if it is spread on valley sides when run-off is likely (eg the ground is sodden or very dry). It can also occur via nutrients entering ground water in permeable areas. Nutrient run-off may be reduced by buffer strips which separate water courses from nearby farm land (see Box 9.1). For appropriate application rates for different substance on different grassland types see Chapter 7.

In general, the introduction of nitrogen and phosphorous into an oligotrophic upland water body will cause an increase in trophic status and thus a change in the associated plant and animal communities. Micro algae such as cyanobacteria and dinoflagellates, which multiply in response to increased nutrient levels, increase the turbidity of the water column and cause a decline in submerged macrophyte species (see also 9.10.3). The turbidity also affects the animals that the water course can support, particularly those requiring clear water and clean gravel beds.

In standing waters dissolved oxygen levels in the surface water layer (the epilimnion) will increase due to enhanced algal photosynthesis. However, increased sedimentation and decomposition will cause de-oxygenation of deeper water (the hypolimnion) and at the sediment surface. The result is a decrease in pH and an accompanying release of nutrients stored in the sediment. It is for this reason that measures to restore lakes which have undergone eutrophication often involve the removal of surface sediment.

Where livestock are allowed to enter a water course, direct defecation will lead to local enrichment, particularly in standing or slow moving waters. Oligotrophic plant and animal communities may then be replaced by those more characteristic of eutrophic conditions. In marginal habitats ruderal plant species such as nettle *Urtica dioica* may encroach into locally enriched areas.

An additional potential problem for freshwater habitats arising from livestock management is the toxic effect of sheep dip (see 9.10.3 and Box 9.6).

Arable

During the twentieth century, arable cultivation, particularly for cereals, has declined dramatically in the uplands with livestock production and associated grassland systems becoming virtually the sole activity. However, in the lower reaches of freshwater systems that originate at higher altitudes, arable farming becomes more widespread and significant to wildlife interests.

Excessive application of organic and inorganic fertiliser are considered to be the main source of pollution of fresh water from agricultural sources (Economic Commission for Europe 1993). The nitrate and phosphate within these fertilisers behave differently when they reach the soil. The nitrate ion is relatively soluble (because it is repelled by the negatively charged soil particles) and so moves into water courses relatively easily. The phosphate ion is readily precipitated as insoluble iron, calcium or aluminium phosphate and is therefore unavailable for uptake by plants. Inputs of phosphate into fresh water arises largely as a result of soil erosion, although it is now suspected that soils may be saturated and acting as a source rather than a sink.

For arable land, applications of fertilisers should not exceed the crop requirement and should also take account of the current levels of nutrients in the soil. The appropriate amount should be applied in one application. Fertilisers, agro-chemicals, lime or other soil improvers should not be applied within the river or lake margin and all fertilisers should be spread in accordance with the *Codes of good agricultural practice* (MAFF 1998g & h).

The leaching of nutrients from cultivated land varies according to the particular crop in question; lowest rates occur from unfertilised permanent grassland, whilst highest rates are associated with fields planted with vegetables. Soil type and nutrient content, climatic and meteorological conditions and crop rotation are also important factors (Economic Commission for Europe 1993).

Land left unvegetated during the winter months is a potential cause of soil erosion. Increased levels of suspended solids in a water body will lead to smothering of submerged plant species. A change in the turbidity of the water and the nature of the substrate, for example from stony to silty, will affect the animals present, particularly certain invertebrates and spawning fish.

Reducing nutrient and sediment run-off in the short term may be addressed by the development of buffer strips which separate water courses from nearby farm land. (See Box 9.1 for details on buffer strips.) However, in the long term changes in agricultural practice are also needed.

Further information: English Nature 1995a; Environment Agency 1998c; MAFF 1992a, 1997c, 1998g & h; MAFF and Welsh Office 1991.

Box 9.1 Establishing buffer areas

Buffer areas

This term is used to describe a strip or zone of vegetation which lies adjacent to a water course and does not receive the nutrients or chemicals applied to the adjacent land. It acts as a ‘sink’ for the substances derived from the adjacent land.

How buffer areas work

Buffer areas work in two ways. They distance the area concerned from the water course, so reducing the likelihood of spray drift or sediment entering the water. In addition, the water that passes through the soil in the buffer area can be chemically transformed to reduce its pollutant load.

Buffer areas can minimise direct contamination with manures, pesticides and fertilisers. In addition buffer areas are a useful tool in controlling soil erosion. For further details see Environment Agency 1996b.

Limitations of buffer areas

Buffer areas are ineffective where the underlying geology is permeable, eg on limestone, although they will still be effective in helping to minimise pesticide drift. The nature of drainage systems in limestone can cause pollution to enter a water course several miles from the source of the pollutant.

The majority of nutrient enrichment arises from nitrate or phosphorous moving through the soil and drains. Much agricultural land is drained and under-drainage will by-pass a buffer area, making it largely ineffective. The buffer area must also be correctly sited to ensure that it intercepts a good proportion of soil water or surface run-off. For example, buffer areas will not be effective where water directly infiltrates ground water or is channelled away from the buffer by site hydrology. The value of buffer areas will be maximised if inputs of nutrients are limited in the upstream catchment, because buffering all streams and ditches in the headwaters may be impractical.

Types of buffer areas

Wooded buffer strips are more effective than well vegetated grass strips at removing nitrogen, whilst vegetated strips are more effective at removing suspended solids (and therefore particulate phosphorous). A combination of both will be the most effective. Bare earth is of no use in controlling diffuse pollution, while a mown grass strip is of limited use.

In some cases pollutants coalesce into discrete areas owing to land form or hydrology. Buffer zones targeted at these areas could negate the need for buffer strips.

Pollution removal

About 80% of the suspended solids in run-off (which may contain phosphorous and pesticides) can be trapped on the surface or infiltrate the buffer area. Buffer areas can also remove nearly all the nitrate in water that passes through them at a depth of less than 30 cm. The soil surface must remain relatively dry for phosphorus to be retained, whilst optimum nitrate removal occurs when the subsoil is wet.. The potential of buffer strips to remove pesticides remains unproven, as the anaerobic conditions favouring the denitrification process (removal of nitrate) are likely to cause the release of pesticides.

Box 9.1 Establishing buffer areas cont.

Value of buffer strips for wildlife

The area at the edge of the buffer strip will be the most effective for diffuse pollution control, while the potential value for wildlife will increase closer to the river itself where nutrient and pesticide levels are low. Obviously the wider the buffer strip the more valuable it will be to wildlife. The wildlife of the water system being protected by the buffer strip, eg aquatic plants, invertebrates, and fish, will also benefit from the reduced inputs.

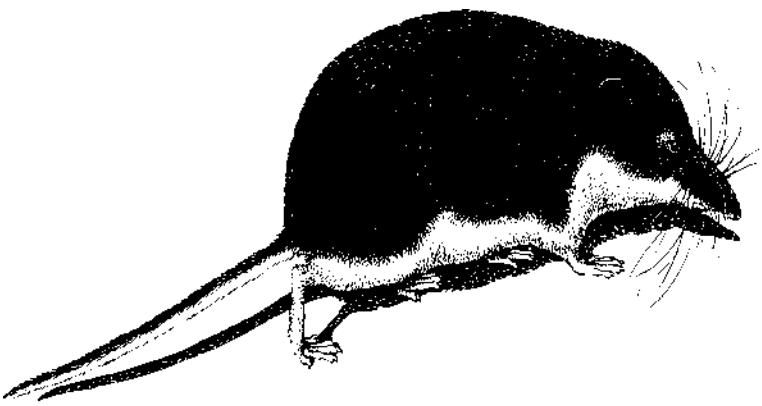
Buffer strip widths

The required width will vary according to whether the strip is required for wildlife value as well as pollution control.

- A strip of minimum 10 m for wildlife has been recommended by Petersen & La Coursiere (1992), but other studies have recommended 30 m or 90 m on rivers with a floodplain.

- For buffer strips required only for pollution control a width of 2-3 m is adequate provided it is well vegetated.

Further information: Environment Agency 1996b; Petersen, Petersen & La Coursiere 1992.



Water shrew

9.9.2 Forestry

The rate of afforestation of upland catchments in England has decreased significantly in the last 15 years. However, large conifer plantations in upland areas have significant effects upon the freshwater systems that drain them. These include altering the hydrology of surrounding areas, changing erosion and sedimentation rates, and affecting water quality.

Changes in hydrology

Deep ploughing of wet areas results in a lowering of the water table and a loss of wetland species. Drains that expose peat areas reduce their capacity to retain water and this can lead to a greater likelihood of flash flooding at some times of year. Conversely, reduced flows may result at other times owing to the reduced capacity of the land to hold water.

Erosion and sedimentation

Extensive drainage operations lead to increased rates of run-off from the ground and increased flows in receiving streams. Streams often lose their natural channels as they are converted into drainage runnels (Nature Conservancy Council 1986a). The increased spate of streams creates greater erosive power leading to sediment transport and re-distribution of sediment deposits. Studies carried out by Battarbee *et al* (1985) compared sediment transport in afforested and unafforested catchments. In lakes with 15-70% afforestation there was a marked increase in sedimentation resulting from soil erosion in the catchment.

Sedimentation resulting from soil erosion in the catchment may lead to changes in the aquatic flora of the receiving water body. Submerged plant communities in particular will suffer from blanketing of the substratum. They may have difficulty in rooting and therefore are more likely to be scoured out in flood conditions. Increased turbidity in the water column will decrease light penetration, thereby inhibiting photosynthesis. The result may be a change from a mixed community of submerged and floating leaved species to dominance by floating leaved species, and, eventually colonisation by marginal emergent species as siltation progresses.

As sedimentation progresses, the aquatic fauna will also change. For example, species requiring clear water and stony beds will be replaced by those adapted to turbid water and soft substratum. Fish spawning can also be affected by sedimentation.

Erosion may also lead to changes in the water chemistry, particularly where high levels of peat are entering the system. This in turn will alter the aquatic communities present to those which are adapted to the new conditions.

Nutrient enrichment

Fertiliser, in the form of rock phosphate, is added to the soil to increase the nutrient status of afforested areas. The result is an almost immediate enrichment of forest streams that drain the affected areas (Nature Conservancy Council 1986a). The effects of nutrient enrichment on plant communities and species have been dealt with in 9.9.1.

Acidification

Coniferous forestry is particularly important in accelerating the process of acidification. The large surface area offered by their leaves enables the trees to accumulate acidifying pollutants from the air in a particulate form (dry deposition) or from mists and fogs (occult deposition).

Waters that have become acidified have a combination of low pH and low concentration of calcium, coupled with a high concentration of aluminium leached from the soil. This combination has a damaging effect on flora and fauna. For example, acidified systems generally support a less diverse macrophyte flora. Tolerant species such as bulbous rush *Juncus bulbosus* and *Sphagnum* spp are likely to proliferate under acid conditions, as a result of reduced competition.

Increased alkalinity due to liming

Liming has been used as a means of ameliorating the effects of acid deposition on fresh water, particularly in relation to restoring declining fish stocks. Liming is either carried out through direct application to the water body or indirectly via the catchment. Direct liming is only effective if applied to a standing water body with a long residence time; in better flushed systems the buffering effect of the lime is rapidly lost. Rivers and streams are often dosed periodically in proportion to their flow, water level and pH.

Catchment liming involves dosing the hydrological source of the water body, usually springs and flushes. It mitigates the effects of acid surges and prevents harmful metals leaking into the water course. However, a number of concerns have been raised over the widespread use of liming as a means of ameliorating the effects of acid deposition.

- The addition of lime to acidified waters does not restore the water body to the pre-acidified state, but, in effect, hardens previously soft waters.
- In some cases liming can cause damage to the catchment comparable with acidification.
- Liming does not stop the input of aluminium to watercourses, although it does convert it to the less toxic non-labile form.
- Liming can cause the loss of nitrate to water courses; the impact of which is uncertain (Farmer 1992).

Liming is likely to affect the flora and fauna of the water body, especially if applied to springs and flushes. Species composition is likely to change because calcifuge species are discouraged. Unless lime-rich water bodies are present nearby, there is unlikely to be colonisation by calcicoles.

Liming of oligotrophic lakes tends to lead to an increase in species diversity, accompanied by changes in dominance. Acidophilic (acid loving) plant species such as the *Sphagnum* mosses tend to decline or disappear, whilst liverworts and filamentous green algae proliferate. Battarbee *et al* (1992) should be consulted for a detailed account of the effects of liming on the macrophyte flora of an oligotrophic system. In addition the increase in alkalinity of limed waters may lead to a transition from ultra-oligotrophic and oligotrophic state to a more species-rich, mesotrophic situation.

Shading

Loss of light on riparian margins can discourage or eliminate plant and animal species.

9.9.3 Mining and quarrying

Mines and quarries are often sited in upland areas, particularly those underlain by limestone. Mining poses a number of environmental problems with relation to fresh waters, in particular the leaching of mine wastes into running or standing waters. The result may be direct pollution of water courses, with the consequent effects on wildlife.

9.10 Direct management issues affecting freshwater habitats

9.10.1 Direct abstraction

Many upland stream, rivers and water bodies have been developed as a source of drinking water for private and public supply. Water is abstracted directly from surface or ground waters, thereby posing a threat to water levels and flow regimes downstream of the abstraction point. Water may also be abstracted for non-consumptive use, for example by hydro-electric power stations or by fish farms. In these cases river flows may be reduced between abstraction and discharge points.

Reducing the flows in rivers can lead to grasses and other vegetation taking over the river bed, making it very difficult for characteristic water plants to return. Low flows also exacerbate the effects of pollution and enrichment. Reduced flushing rates may lead to changes in the physical nature of the river bed or channel.

River flows are normally protected from the impacts of abstraction by the inclusion of prescribed flow conditions in abstraction licences. Under the Water Resources Act 1991, a system of Water Quality Objectives are devised for each water course based upon the use of that river. Abstraction of drinking water is one of the recognised uses (Environment Agency 1996c). These prescribed flows are often set with reference to some statistical measure of low flow such as Q95 (the flow equalled or exceeded for 95% of the time, on average), with an additional allowance to protect other legal users downstream.

SSSIs which have been designated for their aquatic interest may be subject to Water Level Management Plans (WLMPs). Preparation of these plans is a MAFF initiative whereby the water level requirements for a range of activities, including agriculture, flood defence and conservation, can be balanced and integrated. It is the responsibility of the relevant operating authorities (Environment Agency, Internal Drainage Board or Local Authority) to produce and implement these plans. English Nature’s role is to define the nature conservation interest of SSSIs and the water level requirements of the relevant species.

The water level requirements of wetland plants are defined as the upper and lower limits of tolerance to either soil water tables or depth of water, or as a mixture of the two. The water level requirements of rare and scarce wetland plants are given in Table 9.14-9.16.

Further information: Newbold & Mountford 1997.

Effects of over abstraction on plants and animals

Drying of edge and marginal habitats leading to the encroachment of ruderal species. Certain swamp and fen plant communities are characteristic of disturbed habitats and will tend to replace more species-rich assemblages in sub-optimal or disturbed conditions. An example is the *Phragmites australis-Urtica dioica* community, characterised by an understorey of tall dicotyledons such as great hairy willow-herb *Epilobium hirsutum* and stinging nettle *Urtica dioica.* This community of ruderal herbs will out-compete other reed-swamp communities in situations where the marginal edge of watercourses has dried out and become enriched. This will obviously affect the dependent animals.

Reduced flushing rate leading to build up of nutrients. A reduction in water levels will lead to an increased concentration of nutrients. Such an increase could enhance the production of some species at the disadvantage of others. Canadian pondweed *Elodea canadensis*, for example, often proliferates in nutrient enriched waters at the expense of other submerged species. In many cases this dominance by one particular species may only be broken by increasing water levels.

Increased sedimentation. Reduced flushing rates in eroding upland water courses will often result in the deposition of suspended material. Sedimentation will have a smothering effect on submerged animal and plant species, and may fundamentally change the balance of species. Deposition of suspended organic material may change the nature of the surface substratum, leading to a change in the plant and animal communities.

Exposure of normally submerged sub-littoral zones leading to possible reduction in submerged species. Areas normally covered by water may become exposed to the air, reducing the availability of habitat for submerged species.

Box 9.2 Managing abstraction

Abstraction

The Environment Agency is empowered to licence abstractions, to enforce conditions imposed in an abstraction licence, and to take action against illegal abstractions.

When an abstraction is being considered for a water body which has special conservation interests the following steps should be taken:

- Surveys should be carried out to determine the distribution of marginal and submerged communities/species.
- The sensitivity of communities to changes in water level can then be determined using Newbold and Mountford (1997).
- For Sites of Special Scientific Interest the Environment Agency will carry out a hydrological survey for use in the development of a Water Level Management Plan.
- A limit should be set on the extent of change in water levels, in accordance with the findings of the survey.
- The site should then be monitored for species performance and for water levels.

Where there is an existing licence abstraction affecting a water body with special conservation interest, the following steps should be taken:

- Where Water Level Management Plans are being produced, the requirements of the wildlife interest should be taken into account.
- The Environment Agency has a duty to review existing abstraction licences affecting Special Areas of Conservation (SAC), designated under the Habitats Directive, and prepare plans for remedial action.
- In any other situations, work with the Environment Agency and interested parties to develop sustainable water resource strategies on a catchment basis.

Further information: Newbold & Mountford 1997.

9.10.2 Impoundments

Water courses are impounded for a variety of purposes. Running water systems may be impounded to create reservoirs for public water supply, or for hydro-electric power generation. On a smaller scale, individual farmers may dam a stream to raise the water level sufficiently to allow abstraction for irrigation. Some standing waters are impounded to raise water levels for recreational purposes such as fishing, shooting or sailing.

Effects of impoundments on freshwater plants and animals

Impounded streams and rivers will undergo a rise in water level, leading to permanent inundation of both terrestrial and littoral communities. The existing terrestrial plant communities which are flooded may be of considerable wildlife value in themselves, such as the limestone grassland communities of Teesdale which were lost when Cow Green reservoir was created. Plant communities of the littoral zone of standing or running waters have specific habitat requirements in terms of inundation and exposure and are also likely to be lost or adversely affected. Conversely, artificial lakes and reservoirs will be subject to draw down during the summer months as demand for water exceeds supply by rainfall. In this case sub-littoral areas will be exposed leading to a loss of shallow rooting communities.

Impoundments can also have major impacts downstream of the dam or sluice. This includes changing the normal flow regime, which is likely to alter the physical, chemical and biological nature of the water course, and potentially leading to a lack of flushing in the downstream system.

Box 9.3 Managing impoundments

Impoundments

The Reservoirs Act 1975 states that a water body cannot be impounded without due consideration to downstream users.

! Where sites of nature conservation may be affected by impoundments water level management plans should be consulted.

! Surveys should be conducted to determine which plant communities are present at the site.

! An appraisal should be made of the likely impacts changes in water levels will have on particular plant communities and species.

! An appraisal should be made of the likely impacts changes in water levels will have on fish spawning sites.

9.10.3 Aquatic pollutants

Aquatic pollutants include sewage, industrial and farm waste. The impact of a discharge on a freshwater system will depend on the amount discharged, the nature of the pollutant, and the water quality of the receiving water course. Large volumes of pollutant discharged into a small or medium sized river may lead to a rise in water level, thereby altering flow regimes and causing eutrophication.

Organic effluent

Organic effluent such as farm waste (slurry and silage) or sewage are broken down through the action of a range of micro-organisms. This biochemical break down of complex organic molecules utilises oxygen from the surrounding water column resulting in a shortage of dissolved oxygen in the water course downstream of an outfall. The degree of de-oxygenation will depend on:

! the dilution of the effluent in the receiving water course;

! the Biochemical Oxygen Demand (BOD) of the effluent and the receiving water course;

! the nature of the organic material;

! the total organic load of the water body;

! temperature.

Farm effluent such as silage and slurry have an extremely high BOD and if discharged untreated into a water course will cause the complete elimination of the downstream flora and fauna (See Box 9.5 for methods of disposal of farm effluent). Lower strength effluent such as domestic sewage are unlikely to lead to complete elimination of the downstream biota but will tend to cause a change in the structure of the plant community.

Effects of organic effluent on plants and animals

Turbidity and sedimentation. Organic effluent often has high sediment loads associated with it. The resulting increase in the turbidity of the water column reduces the light available for photosynthesis and may lead to the elimination of submerged plants. Sedimentation caused by organic inputs to upland freshwater systems can cause deposition of organically enriched silt. This results in a limitation of the habitat available for animal species, many of which require clean, unsilted cobble or gravel substances for their survival. It can also result in a change in the plant community.

Eutrophication. Eutrophication is the increase in phosphate and nitrogen in a water system. These nutrients, particularly phosphate, are the primary limiting factors of phytoplankton production. Microbial breakdown of organic material, plus direct input of the nutrients from fertiliser run-off, increase the nutrient status of a water body. Increased nutrients cause an increase in plant production, which may block water channels and increase the risk of flooding. The plant assemblages become less diverse and light penetration is reduced, which can limit the area available for plant colonisation. The breakdown of the increased plant material can cause sediment to become silted and anoxic, resulting in the loss of invertebrates and fish. Severe eutrophication in standing water bodies can result in the production of toxic blue-green algae (cyanobacteria).

Box 9.4 Managing sewage effluent

Sewage effluent discharge

The Environment Agency is responsible for issuing numerical consents for discharges to the aquatic environment. The consent system is based on the principle that a discharge with a BOD of 30 mg/l and suspended solid (SS) load of 20 mg/l can be discharged to a water course providing the dilution therein is at least 1:8.

There are a number of inherent problems associated with this system:

- A river with a naturally high suspended solid load (derived from catchment run-off) may receive a number of point source discharges. Assuming all these discharges comply with the specified consent the total suspended solid load of the river may be sufficient to change the ecological state of the river. The problem will be further exacerbated by low flows resulting from dry weather or from abstraction.

- Conventional secondary treatment of sewage using biological filter beds or an activated sludge system facilitates the microbial breakdown of organic material; it does not remove the nitrate and phosphate which result from this break down. The input of nutrients from a number of consented discharges may be sufficient to cause eutrophication in some water courses.

- Some villages and hamlets have no sewage treatment works and rely totally on residential properties having septic tanks and soakways, which can overflow into freshwater systems. Again, there is no removal of nitrate and phosphorous involved.

Options

- For sites with particular conservation value it may be advisable to test background levels of nitrogen, phosphorous and suspended solids in the water course.

- Seek advice on whether the Environment Agency consent system is sufficient to maintain SSSI interest, based on the water quality data above and the N, P and SS loading of the proposed discharge.

Tertiary treatment

For point source discharges of organic effluent, tertiary treatment, which principally involves phosphorous removal, may be a feasible option. This process can involve the precipitation of phosphorous using coagulants of lime, or compounds of aluminium or iron and is approximately 90-95% efficient. Alternative methods are also available, such as reedbeds and lagoons. The cost of phosphate removal for a sewage treatment works is relatively small in comparison with total annual running costs. The EC Waste Water Directive requires Water Authorities to install tertiary treatment where the population is above a certain number (10,000). This usually refers to large sewage treatment works and where the water is deemed sensitive.

An alternative is to divert the phosphorous-rich effluent away from the sensitive water body. The practicality of this option depends on the proximity to a less sensitive water body. All discharges to the sea must now be treated.

Box 9.5 Managing farm waste

Farm waste

The disposal of farm waste is regulated under the Control of Pollution (Silage, Slurry and Agricultural fuel oil) Regulations 1991 (SI 1991 / 324). The Environment Agency is responsible for the enforcement of these regulations, and for issuing consents to discharge from farms. The Ministry of Agriculture Fisheries and Foods have produced a Code of good agricultural practice of the protection of water (MAFF 1998h).

Slurry disposal and storage

Under the Control of Pollution (Silage, Slurry and Agricultural Fuel Oil) Regulations 1991 slurry must be kept in a reception pit or slurry storage tank, unless it is temporarily in a tanker. The Regulations lay down certain rules for most new, substantially enlarged or substantially reconstructed stores, reception pits and channels. The MAFF Code (1998h) provides guidance and gives a detailed description of all the methods employed for slurry storage, such as under floor storage, above ground circular stores, and weeping wall slurry stores. It also deals with the treatment of slurry by mechanical separation, anaerobic digestion and aerobic treatment.

Silage storage

As for slurry, the Control of Pollution (Silage, Slurry and Agricultural Fuel Oil) Regulations 1991 include requirements for the storage and disposal of silage effluent. The MAFF Code (1998h) gives guidance on controlling the amount of effluent generated by silage, designing a silo to prevent the leakage of effluent and methods of disposing of effluent.

Further information: Kelly 1995; MAFF 1991b.

Toxic contaminants

Toxic contaminants, originating from a wide range of sources, can have far-reaching effects on aquatic biota if allowed to enter a water course. There is also the potential for adverse effects on humans where drinking water supplies are involved. Although heavy industry is less common in upland areas, a number of industrial processes require large quantities of fresh water, and are therefore often located on the upland reaches of rivers. An example is the processing of wool for carpets and clothing.

In some upland areas, acid drainage, resulting from the mining of coal or metal ores, is a significant source of toxicity in fresh water. In the case of coal mines, substantial amounts of the mineral pyrite are exposed to the oxidising action of the air and water. The subsequent reaction causes a lowering of pH in the receiving water course, leading to the mobilisation of toxic metals. These waters can often be recognised by a characteristic ochre colour.

Toxic chemicals used on farms, such as pesticides, can enter water courses accidentally if procedures for their correct use and disposal are not observed. (see Box 9.6). They may enter the aquatic system through drift or run-off during crop spraying or during disposal and decontamination activities and may have significant local impact on the biota.

Sheep dip is a particular concern, being the source of major pollution incidents every year (Environment Agency 1998d). All sheep dip formulations pose a hazard to animals (see below). They can also contaminate ground water, rendering it unfit for use. The increasingly used synthetic pyrethroid dip (SP) formulations are about 100 times more toxic to aquatic invertebrates than organophosphorus (OP) formulations, although both have been involved in serious pollution incidents. Sheep dipping activities and the disposal of sheep dip solution must therefore be carried out with great care. Very small quantities of any dip solution can contaminate large volumes of water. Problems can be avoided by simple precautions and planning ahead (see Box 9.6). Implementation of the Ground Water Regulations (1998) will require an assessment of siting and disposal of sheep dip by the Environment Agency. It is important that the potential risks to both aquatic and terrestrial fauna are considered in this assessment.

The use of herbicides close to a water course may lead to seepage and drift into the water and impacts on aquatic flora and fauna. Bracken spraying, for example, is common in the uplands and the herbicide involved, asulam, can cause a slight to moderate check, or even severe check in some cases, in the growth of certain aquatic and wetland plants, such as duckweed *Lemna* sp., bog pondweed *Potamogeton polygonifolius* and lesser spearwort *Ranunculus flammula* (Rhone-Poulenc 1997, see Information Note 6 regarding bracken management).

Effects of aquatic pollutants on plants and animals

Evidence for the impact of toxic chemicals on the aquatic system is often most rapidly shown by the macro-invertebrate communities. But both direct and indirect effects on other groups of organisms (eg by a reduction in the invertebrate food supply) can be significant and often more evident (eg fish kills). Pesticides, including veterinary medicines such as sheep dips, and herbicides, which enter a water course accidentally, can kill aquatic invertebrates and cause browning and death of aquatic plants. In the case of acid mine drainage from disused coal mines, decreases in pH may render the water course unsuitable for certain plants and animals. In addition, as the pH increases with distance downstream, ferric hydroxide precipitates out. This blankets the stream bed, inhibiting the growth of aquatic plants and changing the suitability of the habitat for aquatic animals.

Otter

Box 9.6 Managing toxic contaminants

Toxic contaminants

Since 1991 pollution incidents have been categorised by the Environment Agency on the basis of their severity. Category 1 incidents are the worst and may result in the closure of a source of water abstraction, or extensive fish kills. Of the total number of serious pollution incidents recorded, those resulting from industrial activities (in particular the construction industry) are the most frequent. Prosecutions are always sought when Category 1 incidents occur, if adequate evidence is available (Environment Agency 1996a). The Control of Pesticides 1986 (amended 1997) requires users "to take all reasonable precautions to protect.....creatures and plants.....and in particular to avoid the pollution of water".

Different statutory requirements, codes of practice and guidance is required or available for users of veterinary medicines and pesticides, including:

- the label recommendations;
- the requirements of the Control of Substances Hazardous to Health Regulations (COSHH) 1998;
- the Control of Pesticides Regulations 1986 (as amended 1997);
- the Guidelines for the use of herbicides on weeds in or near watercourses or lakes (MAFF 1995);
- the Code of practice for the safe use of pesticides on farms and holdings (The Green Code, MAFF 1998j);
- the Guidance on storing pesticides for farmers and other professional users (Health and Safety Executive 1997);
- the Sheep dipping: Pollution prevention guidelines no. 12 (Environment Agency 1998d) and sheep dipping leaflet (Health and Safety Executive 1998).

Sheep dip

Careful siting of new dipping facilities, proper use and maintenance of existing dipping facilities, correct management and handling of sheep after dipping, and correct disposal of spent solution and empty containers are all important to prevent water pollution. Some guidelines are provided below, but see Environment Agency 1998c and HSE 1998 for further details on all these aspects. The Ground Water Regulation 1998 will require assessment and authorisation of dipping facilities to prevent entry to ground water of List I and List II substances, including both OP and SP dips. Guidance on the implementation of the Regulation is expected during 1999.

Dip chemicals may also enter rivers through the contamination of effluent from the wool scouring industry. Label withdrawal periods must be observed for the product used, but it is good practice not to shear sheep for three months after dipping.

Box 9.6 Managing toxic contaminants cont.

Siting and design of sheep dips

- See Health and Safety Executive leaflet (1998) for siting and design of sheep dip facilities.
- The dip bath should not have a drainage hole and drip pens should be constructed with impervious floors which drain back into the bath. They should be large enough to hold sheep for at least 10 minutes so that they are not actively dripping when released to secondary holding pens.
- New facilities should be located as far away from any water course or drain as possible, but never less than 10 m, and at least 50 m from any well, spring or borehole.
- For mobile dip facilities, the appropriate place to let sheep drain and the correct method of disposal must be decided beforehand.

Disposal of spent dip

- Before disposal, the EA must be consulted so that they can consider measures needed to protect ground water and issue an authorisation.
- Spent dip must not be tipped into sewers, drains, cesspools or septic tanks and must not be able to run off or seep into any river, stream or ground water.
- Soakaways must not be used for the disposal of used dip and an alternative must be sought.
- One possibility is to use a registered waste disposal contractor.
- In certain circumstances spent dip can be spread thinly onto grassland at certain application rates, but see EA 1998c for further details and conditions. Consult English Nature if within an SSSI because some such areas may be very important for wildlife.

Further information: Environment Agency 1998d; Health and Safety Executive 1998; Veterinary Medicines Directorate publications 1991, 1992, 1993.

Box 9.6 Managing toxic contaminants cont.

Pesticides

The Environment Agency and statutory conservation agencies must be consulted at least 72 hours before any aerial spraying is undertaken. In the case of the conservation agencies, this applies to any aerial spraying application within 1,500 m of an SSSI. Failure to consult may result in prosecution. For ground spraying, follow the Code of practice for the safe use of pesticides on farms and holdings (The Green Code, MAFF 1998j).

! Wherever possible, control weeds by mechanical means.

! A certificate of competence is required for users of pesticides.

! Always follow the label instructions.

! To avoid unnecessary damage to non-target plants apply herbicide by spot treatment or weed wiper where possible.

! Avoid spraying pesticides close to aquatic habitats and follow any label instructions on no-spray zones.

! Avoid spraying in high winds and follow the Green code recommendations on wind speed.

! Use appropriate no-spray buffer zones when spraying adjacent to sites of nature conservation importance (see Cooke 1993 and Information Note 6 Managing bracken).

! Dispose of pesticides and washings safely and follow the Green code.

Further information: Control of Pesticides Regulations 1986 (as amended) (COPR); Cooke 1986, 1993; Control of Substances Hazardous to Health Regulations 1994 (as amended) (COSHH); Information Note 6 Managing bracken; MAFF 1995 & 1998j.

9.10.4 Structural modification of water courses

River channels have been modified in the UK for many purposes including: flood alleviation, agricultural drainage, reducing bank erosion and maintaining navigation. The methods include widening, deepening, straightening and embanking. Although large-scale engineering projects are less common in upland areas, a significant number of upland rivers and streams have undergone some small-scale engineering, usually in the form of channelisation. These types of modifications often result in loss or change of aquatic and riparian habitats.

Re-sectioning is the mechanical re-profiling of river banks and / or bed to produce a larger, more uniform cross-section, which can carry flood flows more effectively. This will usually involve dredging to maintain the cross-section and mowing of bank vegetation. The result is, in general, a loss of physical features, such as riffles, point bars and eroding cliffs.

Bank reinforcement is usually associated with urban areas and major rail or road links, although it can occur wherever there is a danger of bank erosion. On a smaller scale banks may be subject to reinforcement following flooding. Reinforcement may involve the whole bank or just the bottom section. Various materials are used, including concrete, sheet piling, brick, laid stone, rip-rap and rock filled gabion baskets. The immediate result of bank reinforcement is the loss of bank features and vegetation; there may also be an associated change in sediment transport.

Weirs and **sluices** are used as a means of harnessing the power of rivers to drive milling machinery, for water-level, flood control and in conjunction with locks for navigation. These fixed structures hold back water upstream, with a resulting reduction in velocity. Their impact on habitat features is dependent on the nature of the river section. In upland areas weirs appear to have little impact on the physical elements of the stream, such as pools, riffles and point bars. However, the fall in velocity caused by the weir may result in some sedimentation in the upstream section.

Further information: Boon, Calow & Petts 1992; Calow & Petts 1992, 1996a,b,c; Newbold, Purseglove & Holmes 1983; National Rivers Authority 1996; RSPB, NRA & RSNC 1994.

Effects of river engineering on plants and animals

Reduction in channel diversity. River engineering techniques which result in a loss of in-stream physical features will lead to a loss of species diversity. For example, upland riffle systems are normally characterised by a small number of higher plants, such as alternate-flowered water milfoil *Myriophyllum alterniflorum*, shore-weed *Littorella uniflora,* and a wider range of moss and liverwort species such as *Fontinalis antipyretica* and *Solenostoma triste.* In contrast pools or slacks support a broader range of higher plants, such as intermediate water star-wort *Callitriche hamulata*, common water star-wort *C. stagnalis*, floating club rush *Eleogeton fluitans* with a narrower range of non-vascular plnts eg *Sphagnum* moss. Similarly, the wide range of bank and marginal habitats support a characteristic assemblage of species, the diversity of which may be reduced by bank reinforcement.

River engineering may reduce the river margin width, remove or alter shoal and riffle structures and severely alter riparian and aquatic invertebrate communities. This is especially the case for sand and shingle structures, above and below water. Regulating the flow of rivers and streams, especially reducing the periodicity of flow, flash flooding and so on, allows shoal structures to stabilise, or they may remain permanently submerged, potentially wiping out the invertebrate communities. Rivers downstream of reservoirs rarely have shoal faunas of note.

Sedimentation. The physical disturbance associated with any structural modification of the banks or bed of a river will tend to increase levels of suspended solids, and hence increase deposition in the downstream reaches. This problem may be further exacerbated in rivers subject to abstraction (see 9.10.1). Similarly, changes in the flow regime may lead to erosion of the bank and bed downstream of the modified channel. The result in both cases will be a smothering of submerged vegetation. The problems of deposition will be particularly acute where the affected river flows into a lake where the sudden fall in water velocity will cause sediment to settle out. In extreme cases the nature of the substratum may be altered significantly, both in physical structure and trophic status, resulting in a change in the rooted macrophyte flora and the fauna.

Box 9.7 Structural modifications of river channels

The Environment Agency is responsible for balancing the use of water resources in England. However, water courses which are not designated SSSIs are afforded no statutory protection against structural modifications, such as channelisation. The following points aim to provide guidance on the methods available for dealing with the problems which commonly affect upland rivers.

River Bank Erosion

- **Fence off riparian areas**
  Stock fences should be sited some distance from the bank edge to allow establishment of bank vegetation. If vegetation begins to encroach into the channel some cutting or controlled grazing may need to be implemented.

- **Construct vegetated revetments**
  A revetment is a sloping bank protected by stone or some other durable material. The bank should be re-graded to a stable angle. Shelves and shallow berms planted with appropriate marginal species will protect the bank against erosion. For example, grasses will retard flows whilst reeds will consolidate the lower part of the bank.

- **Plant native trees**
  Planting of trees such as alder *Alnus glutinosa* and willow *Salix* spp help to stabilise river banks. However, there are regulations which control how close to the water's edge this is allowed. Note also that alder is subject to a fungal disease (*Phytophora*) and in areas where this is prevalent, use of alder should be avoided (see Environment Agency 1997).

Flood Alleviation

- **Retain the flood plain**
  Avoid any development of or modification to flood plains.

- **Establish distant flood banks**
  Distant flood banks allows a degree of flooding to occur but enables the river to meander naturally. This method of flood prevention is generally the most appropriate in upland gravel bed rivers as it results in minimum impact on the river environment.

- **Partial dredging**
  This option is preferable to full dredging for removal of high spots in the river bed, as it retains areas of undisturbed bed and creates less spoil (RSPB, NRA & RSNC 1994). It does, however, still destroy valuable habitat and does not address the problem of sediment loading to the system.

- **Gravel traps**
  High energy, upland rivers often carry elevated sediment loads, which may cause bank erosion and scouring. Gravel traps are designed to reduce stream velocity over a designated stretch, thereby causing sedimentation. They may take the form of two concrete sills located some distance apart.

  High sediment loads can be caused by overgrazing, a lack of riparian vegetation and moorland drainage. Reducing sediment loading is preferable to managing the sediment once it is in the river. River management should aim to retain the natural fluvial processes wherever possible.

Further information: Environment Agency 1998c; RSPB, NRA & RSNC 1994; MAFF 1997c & 1999b.

Box 9.8 Managing drainage ditches

Drainage ditches

Ditch systems in the uplands include those in moorland and grassland situations. Managing these to maintain the wildlife interest of the surrounding habitat is covered in Chapters 6 and 7 respectively. Towards the lower reaches of water catchments in the uplands, drainage ditches themselves may be of wildlife value. They may support the remnants of ancient wetland communities, and may be the richest wildlife habitats in many agricultural landscapes, supporting a diversity of water plants, invertebrates, amphibians and fish.

Drainage channels are often managed solely to ensure the prevention of flooding. However, small changes in management could also benefit wildlife. For example, management can prevent emergent vegetation such as reeds invading open water areas and out competing submerged aquatic plants.

Options for drainage ditches

! Deeper channels can be re-profiled and a shallow berm or shelf created along selected lengths.

! Generally management should be carried out 'little and often' using hand tools such as scythes and peat spades where possible.

! On-going cycles of ditch dredging on a three to five-year rotation will create areas for recolonisation of water plant species

Further information: Newbold, Honnor & Buckley 1989.

9.10.5 Recreation

The use of natural areas for recreation has increased significantly in recent years, and freshwaters provide a focus for a range of recreational activities. Fishing is an extremely widespread and popular activity, and boating is also popular, especially on many of the larger lakes in Cumbria, and has increased substantially since the 1970s.

Effects of boat activity on freshwater plants and animals

Power boating in particular can have an adverse impact on freshwater plants and is more disruptive than any other recreational activity for the following reasons.

! Physical turbulence caused by wash and propeller action may lead to the loss of rooted macrophyte species and the prevention of their re-establishment.

! Floating and submerged species may also be cut by propeller action.

! Wave action may cause erosion of banks and bank side vegetation.

! Turbidity may be increased in shallow water courses through disturbance of the substrate.

! Marginal and emergent plants may be removed to enable access to the water's edge. The result of their loss may be accelerated bank erosion.

Further information: MacNee & Harvey 1996

Effects of fishing on freshwater plants and animals

Fishing and fisheries management has the potential to provide many practical conservation benefits (Environment Agency 1998b). Most fisheries have some conservation value and this can be readily increased, both for fishing and wildlife, through simple management of habitats, fish and the activities of the anglers themselves. However, some fisheries management procedures can be detrimental both to fisheries and conservation.

Potential problems that may arise from fishing are given below, although it is recognised that angling is often only one of a range of activities which can result in the problems identified.

! Cutting or removing marginal vegetation to allow access to the water's edge can alter the bank profile, and marginal vegetation may be removed and replaced by a grass sward.

! Clearing vegetation and physical structures in river channels can adversely affect plant, fish and invertebrate communities.

! Invasive plant species, such as the Canadian pondweed *Elodea canadensis*, can be introduced into water courses as a result of fishing activity. *E. canadensis* grows rapidly under suitable conditions and may out-compete other submerged species, alter animal communities and hamper future fishing activity.

! Diseases, such as crayfish plague, can be introduced as fungal spores on fishing gear. The recommendation is to sterilise fishing gear with an iodine-based disinfectant when moving between catchments and water bodies.

! Species which are not endemic to that water body may be introduced, either for sport or as live bait, eg roach and pike, and these can prey on and out-compete other species.

! Discarded fishing line and hooks can cause problems for birds, and fishing may disturb breeding and resting birds and other wildlife.

! Conflict with wildlife interests may arise where fish-eating birds are thought to be affecting fishery interests.

! Sensitive macrophyte species may be threatened as a result of grazing by introduced exotic fish species.

! Many fish populations are genetically distinct, and restocking with fish from different populations can have a detrimental effect on the local population. The recommendation is to stock with fish which are genetically similar to the wild stocks, ie non-genetically distinct sources of fish, in order to reduce the possible impacts.

Further information: Environment Agency 1998b

9.10.6 Fish farming

Fish farming has undergone a rapid expansion since 1990, and although much of this expansion has occurred in Scotland, a number of the larger lakes and rivers in the English uplands now support fish farms.

Rainbow trout are the most popular farmed species throughout northern Europe, and can be farmed in fresh or salt water, although they must spawn in fresh water. The brown trout is also farmed, largely to re-stock fishing ponds. Fish farms can be divided into those which are land-based and abstract water from a nearby water body, and those which use cages anchored some distance from the lake shore. In the former case effluent from the production process is normally discharged to the nearest water course.

Farming of crayfish also occurs in England to supply the restaurant and hotel trade. It involves the introduction of larger, non-native crayfish species to ponds and lakes, the most common being the North American signal crayfish *Pacifastacus leniuculus*. These are either retained by some means in a part of the water body or merely added to the pond or lake and not contained at all.

Effects of fish farming on fresh water plants and animals

Eutrophication. Effluent from fish farms has a high organic content in the form of faeces and excess food. Several studies have shown increases in organic and inorganic nitrogen in fresh waters used for cage culture (Phillips 1985). Similarly, localised increases in phosphorous resulting from excretion or leachate from solid waste have been found to occur close to fish cages. Elevated levels of nutrients may in the long term lead to eutrophication of nutrient-poor oligotrophic lakes and running waters, whilst the sediment underneath fish cages may undergo some localised enrichment.

Where nitrogen and phosphorous inputs to oligotrophic systems are elevated as a result of other activities, the additional input from fish farms will contribute to changes in trophic status. In extreme cases increases in nutrients may result in blooms of micro-algae, which increase the turbidity of the water and reduce light penetration. There may also be a long-term change in higher plant and animal communities.

Sedimentation. Organic matter such as faeces and excess food material will be deposited below fish cages. Blanketing of the substratum by organic material will cause changes in the chemical nature of the sediment, and may lead to a change in the rooted macrophyte flora and aquatic fauna. Species characteristic of oligotrophic systems will be out-competed by species that favour more enriched sediments and eutrophic conditions. Sediment loads are very high; 1 tonne of fish (trout) produced / annum is equivalent to the suspended solid load from 854 people (Newbold, Hambrey & Smith 1986).

Introduced species. The escape of farmed fish into the environment can affect native fish stocks. It can introduce inappropriate genetic differences in native stocks, ie non-native genotypes, and may lead to a loss of the native genetic diversity. In addition, there may be a transfer of pathogens and parasites, eg sea lice, to native stock. Chemicals, such as antibiotics, used to combat fish parasites and diseases may also exert some toxicity on freshwater biota.

The import of the signal crayfish for farming purposes has had an enormous impact on the native white-clawed crayfish. Signal crayfish are a vector for crayfish plague which is caused by the fungi

Aphanomyces astaci and is thought to have been introduced into the country in the 1970s (Holdwich, Rogers & Reader 1995). It is spread by signal crayfish escaping from fish farms, by fishermen using live signals as bait and on fishing gear. Crayfish plague has destroyed many native populations. MAFF have identified 'no-go' areas and permissible areas for crayfish farms, to protect river systems unaffected by the disease (MAFF 1996a).

9.10.7 Controlling nuisance vegetation

The majority of upland rivers and lakes are oligotrophic, and the growth of native plants usually causes few problems. Exceptions occur where upland waters receive organic enrichment such as fertiliser run-off, or slurry effluent, or where invasive plants are present. Impacts may include the development of algal blooms, including blooms of blue-green algae which may produce toxins (such as *Anabaena* spp.). Excessive growth of vascular plants may also result. These changes may interfere with other uses of the water body, such as water abstraction or hydroelectric power generation. Problems associated with excessive plant growth include an inability to use the water for drinking purposes, impeded flows, siltation, the blockage of pumps and filters and interference with recreational activity. The ecosystem may change as a result of competition for light by the invasive species and de-oxygenation of the water column by decaying plant material. (See Boxes 9.10 and 9.11.)

A number of exotic plant species were introduced to Britain during the nineteenth century, largely for ornamental purposes. Some of these species are highly invasive and will out-compete native species. Himalayan balsam *Impatiens glandulifera*, for example, occurs throughout the British Isles and forms extensive stands on river banks. It changes the riparian vegetation by shading out native plants and also threatens the invertebrate communities which the native flora supports, as well as those reliant on the open sand, silt or shingle shoals and bars which the plant invades. Introduced and invasive species are listed under Schedule 9 of the Wildlife and Countryside Act 1981 and as such it is an offence to plant or cause these species to grow in the wild.

Further information: National Rivers Authority 1994; Dawson 1992

Box 9.9 Managing fish farms

Several authorities have responsibility for the control of fish farming activity. Planning permission must be sought from the local authority, licences are required from MAFF for the purposes of disease control and a discharge consent must be obtained from the Environment Agency.

Treatment of effluent from land based fish farms

Options

- **Settlement treatment system**
  These systems are effective in removing solid waste from fish farm effluent. Retention time within the system is important as small less dense particles will require longer to settle out.

- **Filtration or screening system**
  Where solid levels are low a single stationary mesh may be sufficient. Effluent with a higher solid content may require a self-cleaning or rotating filter.

Treatment of effluent from cage fish farms

Options

- **Collection of solids**
  Solid waste can be prevented from reaching the substratum by suspending a funnel device below fish cages. The waste accumulates in the collection apparatus and is pumped out at intervals for treatment.

- **Feeding regime**
  Careful feeding minimises waste and reduces cost. Hand feeding produces less waste than mechanical hoppers.

- **Use of antibiotics**
  Use of prophylactic antibiotics in food should be minimised. Dead/ill fish should be removed daily. Antibiotics should only be applied to treat diseases.

- **Use of chemicals**
  Follow manufacturers' instructions. Ensure correct dilution is used.

Preventing spread of crayfish plague

- Ensure non-native crayfish cannot escape from the water body.

- Ensure waste water is not discharged to water bodies capable of supporting native crayfish.

- Ensure fishing gear is sterilised with iodine when transferring between water bodies.

Further information Environment Agency 1998b; MAFF 1996a; Nature Conservancy Council 1990c; Newbold, Hambrey & Smith 1986; Phillips 1985.

Box 9.10 Controlling nuisance vegetation

Nuisance vegetation

A range of techniques exist for the control of nuisance aquatic vegetation. These can be divided broadly into physical, chemical and biological techniques.

Physical control

A range of techniques are available of which **cutting, dredging** and **shading** are the most widely used. Although mechanical control achieves immediate results these methods only produce a relatively short-term solution to the problem.

Cutting

! Cutting of native species can be carried out either by hand or mechanically from a boat, depending on water depth.

! Cut or dredged material should be removed from the watercourse and disposed of carefully to avoid damaging riparian vegetation and any release of nutrients back into the water course.

! Cutting should be timed appropriately to avoid damaging any wildlife interests. For example, avoiding bird nesting times, the flowering time of desirable plants, the emergence time of desirable invertebrates, and the spawning times for fish.

! Cutting may need to be repeated frequently as it tends to stimulate re-growth.

Note: Cutting alien species can make the problem worse rather than better.

Dredging

! Dredge alternate lengths to allow recolonisation by plants and animals.

! Leave patches of weed on the margins of the channel, or mid-stream, to act as refuges for recolonisation.

Shading

! By reducing light penetration into the water column the biomass of nuisance species can be reduced.

! For small areas material such as black plastic sheeting can be used to cover the water body.

! A more long-term (although possibly less effective) solution is to plant trees and tall plants on the south side of a water course or encourage the growth of floating leaved plants.

Box 9.10 Controlling nuisance vegetation cont.

Chemical control

Chemical control of vegetation is achieved through the use of herbicides, most of which are broad spectrum herbicides and not specific to individual plant species. The results may last longer than physical methods, but may be less predictable. Great care should be taken to avoid unacceptable effects on non-target species. Use of chemicals may not be possible for all watercourses, depending upon the use of the site. Use of herbicides requires a specialist knowledge if damage to other vegetation is to be avoided. A certificate of competence is also required for users of pesticides.

Only herbicides approved for use in or near water may be used in rivers or on banks (see HSE Pesticides Safety Directorate booklet 500, published annually). The Environment Agency must always be consulted. Some locations are unsuitable for herbicide application (eg close to a public drinking water supply, see National Rivers Authority 1995).

- Use herbicide only when strictly necessary.
- Identify the target weed and check that it is susceptible to the product and that the product is approved for use (MAFF booklet B 2078, MAFF 1995, Pesticides Safety Directorate booklet 500 (MAFF / Health and Safety Directive - annual publication) and product label).
- Consult the pollution control department of the EA to obtain permission for use of the product in the circumstances of the proposed use.
- Check that the application site is not an SSSI, that there is no risk to any SSSIs from applications (eg downstream) and that rare plants or other species are not present and likely to be affected.
- Where an SSSI is involved in any way, consult English Nature.
- Check that there are no poisonous plants to which livestock may have access; these may become palatable after treatment.
- Only undertake at times which avoid damaging the wildlife interest present.
- Never spray more than a third of the vegetation at any one time.
- Do not repeat the spraying on an area either within the same or the next year.
- Avoid any rare species which might be harmed by the herbicide.
- Ensure operators are fully trained and certificated, and that all applications are carried out within the rules laid down by the relevant regulations and legislation (see below).

Relevant regulations and codes

Control of Pesticides Regulations 1986
The Control of Substances Hazardous to Health Regulations (COSHH) 1998
Wildlife and Countryside Act 1981
The code of practice for the safe use of pesticides on farms and holdings (the Green code, MAFF 1998j).

Further information: MAFF 1995; Newbold, Honnor & Buckley 1989; National Rivers Authority 1994; Tuffnell 1995.

Biological control

Biological control may involve the use of grazing animals, or other plant species. Cattle, ducks and geese, and some species of fish can provide effective control of aquatic and marginal vegetation. The introduction of the exotic grass carp requires a licence and is only endorsed within water bodies which are totally enclosed so that the species cannot escape. Grazing animals, such as cattle, can cause extensive damage to some aquatic habitats and it is impossible to target nuisance species. As such their use in sensitive sites is not recommended.

Box 9.11 Control techniques for a range of invasive plant species

Species	Habitat	Appropriate control
New Zealand pygmy-weed (also known as Australian swamp stonecrop) *Crassula helmsii*	Damp soil in or near water at depths of 0.5 m above water level to 3 m water depth. Can tolerate wide range of pH and alkalinity.	! Ensure that the plant has been accurately identified. Expert advice may need to be sought. Associated species should also be identified to ensure that vulnerable species can be safeguarded. ! Where small areas of land are affected (<20 m^2) opaque material can be used to cover the area, thereby excluding light. ! Medium sized areas (20-100 m^2) and large areas (>2,000m^2) should be treated with herbicide. Diquat is recommended for both submerged and emergent plants. ! When spraying emergent plants a wire mesh should be placed around the affected area to prevent reinfection by small pieces of shoot released after treatment. ! In all cases the area should be monitored for the re-appearance of *C. helmsii* and areas of re-growth spot treated. ! Management may be needed for several years.
Canadian pondweed *Elodea canadensis*	Submerged, in mesotrophic waters, but will tolerate oligotrophic situations.	! Direct removal. ! Herbicide used to control re-growth. ! Control of nutrients. ! Management may be needed for several years.

Box 9.11 Control techniques for a range of invasive plant species cont.		
Species	**Habitat**	**Appropriate control**
Japanese knotweed *Fallopia japonica*	Can colonise most habitats, eg river banks, woodlands, grasslands	! Control can either be by mechanical means such as cutting or grazing, or by chemical means through the use of herbicides. ! Glyphosate is the most effective and commonly used herbicide, but will damage non-target plants and so in areas of wildlife interest its use as a spray is only advisable when dealing with dense stands of the target plant. ! Control should be started in the upper most reaches. ! Priority should be given to areas which have been recently colonised. ! Ensure that all vehicles, equipment and clothing is free of seed and plant fragments before leaving the site. ! Do not dump any cut material or spread any soil contaminated with seed or plant fragments. ! Management may be needed for several years.
Himalayan balsam *Impatiens glandulifera*	Occurs throughout the British Isles; forms extensive stands on river banks	! As for Japanese knotweed.
Giant hogweed *Heracleum mentagazzianum*	Occurs widely throughout the British Isles especially along river banks NOTE: The sap can cause severe skin burns in reaction with sunlight and this plant should be managed with great care.	! As for Japanese knotweed, plus the following. ! Cut large plants before they set seed, taking care to ensure sap does not come into contact with the skin. ! Weed wipe smaller plants with glyphosate. ! Spray seedlings with glyphosate, this herbicide will damage non-target plants and so in areas of wildlife interest its use as a spray is only advisable when dealing with dense stands of the target plant. ! Management may be needed for several years.

9.10.8 Managing small water bodies

Small oligotrophic standing waters in upland areas are known as tarns. Because of their reduced dilution capacity and low nutrient status tarns are vulnerable to changes in water quality. Managing tarns therefore incorporates a number of the issues discussed in 9.9 and 9.10. These are summarised in Box 9.12.

Further information: Biggs *et al* 1994; Drake *et al* 1996.

Box 9.12 Oligotrophic tarns

Nutrient enrichment

The introduction of nutrients into small water bodies, either through catchment run-off or from cattle faeces, can have a profound effect on trophic status. Depending on the source of enrichment a number of methods can be used to combat the causes and effects of eutrophication.

Catchment run-off

! Reduce fertiliser applications within the catchment (see Boxes 9.1 and 9.3).

! Establish a buffer area around the water body.

Poaching by stock

! Fence pond / tarn margins (see MAFF 1999b).

! Stock may need to be excluded from margins if poaching or enrichment from dunging is severe. This will also mitigate the problems of erosion and puddling of tarn edges by cattle.

Managing vegetation

! Where changes in trophic status owing to enrichment have led to domination by one species a cutting regime may need to be introduced to restore the balance of species**.**

! If alien species appear (in an oligotrophic tarn this may include *Potamogeton pectinatus* or *Elodea canadensis*) seek advice regarding total removal of that species.

9.11 Techniques to create freshwater habitats

The protection of existing freshwater habitats is normally preferable to the creation of new ones as established habitats generally offer a larger number of ecological niches and therefore support a wider diversity of species. Standing water habitats, such as reservoirs and gravel pits, are created for purposes other than nature conservation, but appropriate management will maximise their wildlife value. There are a number of publications which provide advice on construction techniques. These are listed in Chapter 11.

9.11.1 Creating a standing water habitat

Several points should be considered when planning a standing water habitat. First, care should be taken not to destroy any existing wetland habitats with their associated flora and fauna. Marshy grasslands, swamps and fens will be located at the lowest point in the drainage basin. Flooding to create a standing water body will result in the loss of these potentially more valuable marginal habitats. Naturally wet hollows, flushes and so on are intrinsically valuable for certain groups of invertebrates, notably craneflies, soldier flies, some ground beetles and spiders. Many are specific to these habitats and are easily eliminated if they are excavated to create standing water. Equally, the creation of a standing water body diverts water from other aquatic habitats within the catchment and may lead indirectly to their loss.

The topography and hydrological conditions of an area will determine its suitability for a standing water habitat. Some sites will naturally hold water if excavated to a sufficient depth, eg to the water table, or to impermeable strata. Alternatively, an artificial liner can be used to prevent seepage. Liners can be made from a variety of materials, including clay, concrete and PVC. The source of water should be established at the planning stage. Potential fluctuations in water level and the periodicity of flooding will determine the type of habitat that may be created and the plant species that will establish. For example, in sites where there is considerable summer draw-down edge species, such as six-stamened waterwort *Elatine hexandra,* that benefit from frequent wetting and drying may establish.

The length of the shoreline can be maximised by creating an irregularly shaped water body, and the diversity enhanced by leaving surfaces uneven rather than smoothly graded. The incorporation of bays and inlets will allow for the establishment of vegetation which may be sensitive to erosion or wave-washing.

Local water quality should be investigated for sources of pollution. In particular, high nutrient levels in catchment run-off can lead to eutrophication of standing waters. Suspended solid loads will affect the rate at which siltation occurs, and will determine whether silt traps should be incorporated into the design of a new habitat.

Water depth is fundamental in determining which plant species will establish. Emergent species can grow in up to 1 m of water. By creating areas of variable depth invasive emergent species, such as reed *Phragmites australis,* can be controlled. The growth of submerged plants is controlled by the level of light penetration, but in general they will grow in depths of up to 2 m.

The size of the water body is also important. Small sites are likely to become choked with emergent vegetation more rapidly than larger sites. Larger sites may also provide greater potential for a range of wildlife including fish, birds and plants.

9.11.2 Creating marginal habitats

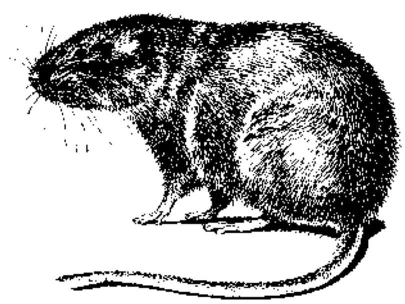
In association with running or standing waters marginal habitats increase the structural diversity of a site and as such increase its value for other wildlife. Various techniques have been developed for establishing emergent and bank side vegetation. If natural recolonisation is not appropriate, material derived from a variety of sources can be planted and established by various methods, to be followed by appropriate aftercare and management. Reedbeds have been successfully re-created and this is well documented. Re-creation techniques for other wetland habitats, however, are less well developed.

Further information: Hawke & José 1995; International Waterfowl Research Bureau 1972; RSPB, NRA & RSNC 1994.

9.11.3 Creating conservation features in running water habitats

Traditionally, managing river channels for purposes such as land drainage and flood defence has resulted in the loss of river habitat features, and hence reduced their value for nature conservation. However, more recently a number of 'soft' engineering techniques have been adopted. Features such as shoals and islands, pools and riffles, vegetated margins and backwaters can be created in existing river channels to enhance structural diversity. Upland rivers tend to carry large quantities of suspended material and therefore have a much greater erosive power. As a result river restoration schemes in upland areas must be carefully planned with due consideration to the hydrology of each individual site. A summary of features is presented in Box 9.13.

Further information: Brookes & Agate 1997; RSPB, NRA & RSNC 1994.



Water vole

Box 9.13 Conservation features in running water habitats

Shoals and islands

- Increase structural diversity.
- Provide refuges for animals and plants away from human disturbance and grazing.
- Current velocity tends to increase around islands thereby creating silt free conditions, favourable for submerged plants.
- Islands can be created from spoil dredged from adjacent stretches of river and protected from erosion by planting emergent vegetation such as reeds on the upstream end.

Pools and riffles

- Pools and riffle systems are characteristic features of upland gravel-bed rivers.
- They occur as a result of variations in the profile of the river bed which causes changes in current speed and water depth.
- Pools and riffles support markedly different assemblages of both plant and invertebrate species and are therefore extremely valuable structural features.

The following guidelines have been developed for reinstating pools and riffles (Brookes 1990):

- Channel and flow characteristics should be assessed to determine if pools and riffles are appropriate features.
- The size and spacing should be determined; typically six times the channel width for riffles.
- Identify and locate the size of the bed material to be used in riffle formations.
- Riffles should be 300 - 500 mm above the natural gradient, pools should be a minimum of 300 mm deep.
- Individual pools and riffles should be between one and three channel widths long.
- Use should be made of the natural meandering of the channel so that pools are formed on the outside of bends with diagonal riffles at the exit.

Unvegetated point bars

- Several invertebrates are totally dependent on the exposed riverine sediments of unvegetated point bars, which is why it is important to retain the natural fluvial geomorphology of a river.

Table 9.3 Nationally rare and scarce aquatic and wetland plants associated with upland freshwater habitats in England

Plant species	Status	Distribution in upland Natural Areas of England
Aquatics		
Elatine hexandra six-stamened waterwort	LR-ns	Cumbria Fells & Dales, Bodmin Moor, Dartmoor
Isoetes echinospora spring quillwort	LR-ns	Cumbria Fells & Dales, Bodmin Moor, Dartmoor
Luronium natans floating water-plantain	Annex IIb Sched. 8 of WCA LR-ns Priority	Cumbria Fells & Dales, Southern Pennines
Najas flexilis slender naiad	Annex IIb Sched. 8 of WCA LR-ns Priority	Cumbria Fells & Dales
Pilularia globulifera pillwort	LR-ns Priority	Cumbria Fells & Dales, Dartmoor, Black Mountains and Golden Valley
Potamogeton coloratus fen pondweed	LR-ns	Cumbria Fells & Dales, Exmoor and the Quantocks
Potamogeton compressus grass-wrack pondweed	LR-ns Priority	Border Uplands
Potamogeton trichoides hairlike pondweed	LR-ns	Cumbria Fells & Dales, Exmoor and the Quantocks
Marginal / inundation		
Calamagrostis purpurea ssp *phragmitoides* Scandinavian small-reed	LR-nt	Cumbria Fells & Dales
Calamagrostis stricta narrow small-reed	LR-nt	Yorkshire Dales, Southern Pennines
Carex appropinquata fibrous tussock-sedge	LR-ns	Yorkshire Dales
Carex elongata elongated sedge	LR-ns	Cumbria Fells & Dales
Circuta virosa cowbane	LR-ns	Border Uplands
Eleocharis austriaca northern spike-rush	LR-nt	Forest of Bowland, Yorkshire Dales, Border Uplands, Southern Pennines
Juncus filiformis thread rush	LR-ns	Forest of Bowland, Yorkshire Dales, North Pennines, Cumbrian Fells & Dales
Limosella aquatica mudwort	LR-ns	Cumbrian Fells & Dales, South West Peak
Mentha pulegium pennyroyal	Vu Priority Sched. 8 of WCA	Exmoor and the Quantocks

Plant species	Status	Distribution in upland Natural Areas of England
Persicaria mitis tasteless water-pepper	LR-ns	Border Uplands, Shropshire Hills
Teucrium scordium water germander	VU	Exmoor and the Quantocks
Thelypteris palustris marsh fern	LR-ns	North Pennines, Cumbria Fells & Dales, Dark Peak

Key to Table 9.3

Annex IIb - listed on Annex IIb of the EC Habitats and Species Directive

Sched. 8 of WCA - listed on schedule 8 of the Wildlife & Countryside Act.

Red list categories

EN - endangered

VU - vulnerable

LR - nt - Lower risk - near threatened

LR - ns - Lower risk - nationally scarce.

Biodiversity Action Plan (BAP)

Priority - Priority species from UK Steering Group 1995 and UK Biodiversity Group 1998.

Sources

Most information from Hodgetts, Palmer & Wigginton 1996; Porley & McDonnell 1997; Stewart, Pearman & Preston, 1994 and Wigginton 1999

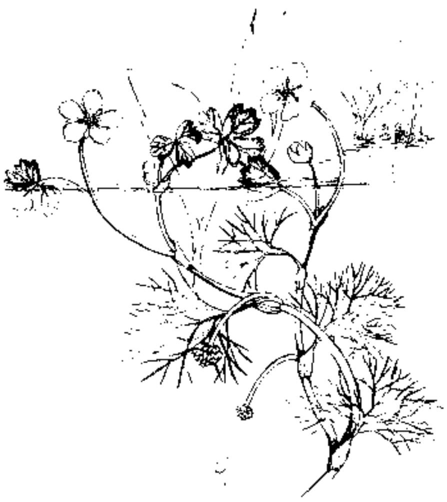


Table 9.4 Nationally rare and scarce bryophytes and lichens associated with upland freshwater habitats in England

Bryophyte and lichen species	Status	Distribution in upland Natural Areas of England
Bryum gemmiparum a moss	EN	Exmoor and the Quantocks
Collema dichotomum river jelly lichen	Sched. 8 of WCA VU Priority	Cumbria Fells & Dales
Fissidens monguillonii a moss	LR-nt	Dartmoor
Fissidens polyphyllus a moss	LR-ns	Dartmoor, Bodmin Moor
Fissidens rufulus a moss	LR-ns	Border Uplands, North Pennines, Yorkshire Dales, Cumbria Fells & Dales, Pennine Dales Fringe
Fissidens serrulatus a moss	VU	Dartmoor
Hygrohypnum dilatatum a moss	LR-ns	Border Uplands, Cumbria Fells & Dales
Jubula hutchisiae a liverwort	LR-ns	Southern Pennines, Dartmoor
Porella pinnata a liverwort	LR-ns	Cumbria Fells & Dales, Exmoor and the Quantocks, Dartmoor, Bodmin Moor
Radula voluta a liverwort	LR-nt	Cumbria Fells & Dales
Rhynchostegium alopecuroides a moss	LR-ns	South West Peak, Exmoor and the Quantocks, Dartmoor, Bodmin Moor
Schistidium alpicola var. alpicola a moss	LR-ns	Yorkshire Dales
Thamnobryum cataractarum a moss	VU Priority	Yorkshire Dales

Key to Table 9.4

Sched. 8 of WCA - listed on schedule 8 of the Wildlife & Countryside Act.

Red list categories

EN - endangered
VU - vulnerable
LR - nt - Lower risk - near threatened
LR - ns - Lower risk - nationally scarce.

Biodiversity Action Plan (BAP)

Priority - Priority species from UK Steering Group 1995 and UK Biodiversity Group 1998.

Sources

Most information from Hodgetts, Palmer & Wigginton 1996; Porley & McDonnell 1997; Stewart, Pearman & Preston 1994 and Wigginton 1999.

Table 9.5 Aquatic plant communities associated with upland freshwater habitats in England (ordered according to standing water types)

Standing water type[1]	Description	Inclusion in Annex 1 of the EC Habitats Directive[2]	Upland Natural Areas of England where community occurs
2	Small, oligotrophic, upland tarns in the Lake District. Typical species: *Juncus bulbosus, Potamogeton polygonifolius.*	Oligotrophic to mesotrophic standing waters of plains to subalpine levels of the Continental and Alpine Region and mountain areas of other regions, with vegetation belonging to *Littorelletea uniflorae* and / or *Isoeto-Nanojuncetea.*	Cumbria Fells & Dales
3	Large oligotrophic lakes on base-poor rock. Typical species: As Type 2 plus *Myriophyllum alterniflorum, Isoetes lacustris.*	Oligotrophic to mesotrophic standing waters of plains to subalpine levels of the Continental and Alpine Region and mountain areas of other regions, with vegetation belonging to *Littorelletea uniflorae* and / or *Isoeto-Nanojuncetea.*	Cumbria Fells & Dales
4	Mesotrophic lakes with some acid and calcareous influence. Often marl sites with species-rich assemblage of water plants, eg *Potamogeton filiformis, Potamogeton praelongus.*	-	Cumbria Fells & Dales Bodmin Moor
5	Mesotrophic lakes on slightly base-rich rock. Species include: *Littorella uniflora, Elodea canadensis, Nymphaea alba.*	Oligotrophic to mesotrophic standing waters of plains to subalpine levels of the Continental and Alpine Region and mountain areas of other regions, with vegetation belonging to *Littorelletea uniflorae* and / or *Isoeto-Nanojuncetea.*	Cumbria Fells & Dales
8	Meso-oligotrophic waters typified by meres of glacial origin. Poor in open water species, rich in emergents. Typical species *Lemna minor, Callitriche stagnalis.*	-	Cumbria Fells & Dales, North York Moors
9	Meso-eutrophic sites generally dominated by water lilies (*Nuphar lutea, Nymphaea alba*).	-	Cumbria Fells & Dales
10	Eutrophic water bodies based on fine substrates often calcareous in nature. Typical species; *Myriophyllum spicatum, Potamogeton pectinatus.*	-	Cumbria Fells & Dales, Yorkshire Dales

Key

1. Taken from Palmer, Bell & Butterfield 1992.

2. Taken from Brown *et al* 1997. * Priority habitat.

Table 9.6 River types of upland Natural Areas in England

River type[1]	Description
Group A	
2	Lowland, clay-dominated rivers.
Group B	
5	Sandstone, mudstone and hard limestone rivers of England and Wales
6	Sandstone, mudstone and hard limestone rivers of Scotland and northern England
Group C	
7	Mesotrophic rivers dominated by gravels, pebbles and cobbles
8	Oligo-mesotrophic rivers
Group D	
9	Oligotrophic, low-altitude rivers
10	Ultra-oligotrophic rivers

1. Taken from Holmes 1983 & Holmes, Boon & Rowell 1998.
   Distribution information for these river types for upland Natural Areas is not available owing to the recent revision of this classification system.
   This classification system is not referred to the interpretation of Annex 1 of the EC Habitats Directive (Brown *et al* 1997).

Table 9.7 Swamp and fen communities of upland Natural Areas in England

NVC code	NVC name[1]	Inclusion in Annex 1 of the EC Habitats Directive[2]	Upland Natural Areas of England where community occurs
S1	*Carex elata* swamp	-	Cumbria Fells & Dales
S2	*Cladium mariscus* swamp and sedge beds	-	Cumbria Fells & Dales
S4	*Phragmites australis* swamp and sedge bed	-	Border Uplands Cumbria Fells & Dales
S5	*Glyceria maxima* swamp	-	Southern Pennines
S8	*Schoenoplectus lacustris* spp. *lacustris* swamp	-	Cumbria Fells & Dales
S9	*Carex rostrata* swamp	-	Border Uplands Cumbria Fells & Dales
S10	*Equisetum fluviatile* swamp	-	Border Uplands Cumbria Fells & Dales
S12	*Typha latifolia* swamp	-	Border Uplands Yorkshire Dales Southern Pennines Cumbria Fells & Dales
S14	*Sparganium erectum* swamp	-	Southern Pennines Cumbria Fells & Dales
S19	*Eleocharis palustris* swamp	-	Cumbria Fells & Dales
S23	Other water margin vegetation. *Glyceria sparganion*	-	Southern Pennines
S24	*Phragmites australis - Peucedanum palustre* tall-herb fen	-	Southern Pennines
S27	*Carex rostrata-Potentilla palustre* tall-herb fen	Transition mires and quaking bogs	Border Uplands Cumbria Fells & Dales, South West Peak
S28	*Phalaris arundinacea* tall-herb fen	-	Cumbria Fells & Dales

Key

1. Taken from Rodwell 1995.
2. Taken from Brown *et al* 1997.

Table 9.8 Breeding birds associated with upland freshwater habitats in England

(Note: See also Chapters 6 and 7 for species predominantly of moorland or grassland)

Bird species[1]	**Birds of conservation concern in the UK**[2]	**Listed on Schedule 1 of the 1981 Wildlife & Countryside Act**	**Listed on Annex 1 of the EC Birds Directive**	**No. of British 10 km squares with breeding records 1988-90**	**% of breeding records in upland ITE squares**[3]	**Main upland habitat associations**	**Principal upland Natural Areas supporting the species *= major/important areas**[4]
Wigeon *Anas penelope*	Amber list	-	-	128	74.2	Moorland and Fresh waters	2, 4*, 8*, 14
Teal *Anas crecca*	Amber list	-	-	571	52.5	Moorland and Fresh waters	2*, 4*, 8*, 12*, 14, 25
Goosander *Mergus merganser*	-	-	-	398	68.1	Fresh waters	2*, 4*, 8*, 10*, 12, 15, 17
Osprey *Pandion haliaetus*	Red list	!	!	39	64.1	Fresh waters	None as yet
Common sandpiper *Actitis hypoleucus*	-	-	-	1,057	69.5	Fresh waters	2*, 4*, 8*, 10*, 12*, 14*, 15*, 25*, 29*, 30, 41, 42, 58, 60, 92
Black-headed gull *Larus ridibundus*	-	-	-	671	46.2	Moorland and Fresh waters	2*,4*,8*,10*,12*,14,17
Common gull *Larus canus*	Amber list	-	-	577	62.4	Moorland and Fresh waters	2*, 4
Grey wagtail *Motacilla cinerea*	-	-	-	1,657	39.6	Fresh waters	All areas
Dipper *Cinclus cinclus*	-	-	-	1,097	56.2	Fresh waters	2*, 4*, 8*, 10*, 12*, 14*, 15, 17, 25*, 29, 30, 41, 42, 58, 60, 87*, 92*, 94*

Key to Table 9.8

1. Upland breeding bird species as identified in Stillman & Brown 1994.
2. From RSPB 1996.
3. From Bunce & Barr 1988, using the 13 ITE land classes which were regarded as upland (information not available on an English basis).
4. The following 18 Natural Areas are classed as upland by English Nature:

No	Natural Area name	No	Natural Area name
2	Border Uplands	29	South West Peak
4	North Pennines	30	White Peak
8	Yorkshire Dales	41	Oswestry Uplands
10	Cumbria Fells & Dales	42	Shropshire Hills
12	Forest of Bowland	58	Clun and North West Herefordshire Hills
14	Southern Pennines	60	Black Mountains and Golden Valley
15	Pennine Dales Fringe	87	Exmoor and the Quantocks
17	North York Moors and Hills	92	Dartmoor
25	Dark Peak.	94	Bodmin Moor

Table 9.9 Nationally rare and scarce invertebrates associated with upland freshwater habitats in England

Invertebrate species		Nature conservation status	Typical habitat	Distribution in upland England (not currently available in terms of NaturalAreas)
Scientific name	**English name**			
Bugs				
Saldula fucicola	Shore bug	Nationally Scarce	Bare gravel and sand beside lakes, rivers and streams	Northumberland, Cumbria
Flies				
Agrypnia crassicornis	Caddis fly	RDB1	In *Chara* beds in large lakes	Malham Tarn
Chelifera astigma	Small dance fly	RDB1	Wooded upland streams	Herefordshire, Yorkshire
Cyrnus isolutus	Caddis fly	RBDK	Rocky shore of large water bodies	Blelham Tarn, Cumbria; Berkshire
Dicranota gracilipes	Cranefly	Nationally scarce	Stony rivers and streams with *Phalaris* at the margins	Peak District, Gloucestershire, Herefordshire, Westmorland
Dicranota guerini	Cranefly	Nationally scarce	Springs, streams, boggy flushes, usually with well vegetated margins	Northern England to Cheshire
Dicranota simulans	Cranefly	RDB3	Upland streams with shingly margins	Northern England, Peak District
Eristalis rupium	Hoverfly	Nationally scarce	Pools, flushes	Northern England
Glossosoma intermedium	Caddis fly	RDB3	Fast-flowing stony streams	Lake District
Hilara barbipes	Dance fly	Nationally Scarce	Banks of streams and rivers	Herefordshire (Monnow)
Hydroptila sylvestris	Caddis fly	RDBK	Unknown	Lake District
Ichthytrichia clavata	Caddis fly	RDB3	Fast-flowing rivers	Lake District, Hampshire
Limonia stylifera	Cranefly	RDB2	Base-rich flushes	Moor House, Westmorland
Limnophila mundata	Cranefly	Nationally Scarce	Upland streams, usually with alders but also unshaded	Northern England to the Forest of Dean
Rhamphomyia obscura	Dance fly	Nationally Scarce	Moorland and pools, lowland bogs	Shropshire, Yorkshire, Cumbria
Setodes argentipunctellus	Caddis fly	RDB3	Shores of large stony lakes	Windermere, Coniston
Tachydromia acklandi	Small dance fly	RDB3	Shingle banks of uplands streams and rivers	Herefordshire, Rivers North and South Tyne, Northumberland

Invertebrate species		Nature conservation status	Typical habitat	Distribution in upland England (not currently available in terms of NaturalAreas)
Scientific name	English name			
Tachydromia woodi	Small dance fly	RDB1	River shingle and sandy banks	Herefordshire (R. Monnow), Yorkshire (R. Wharfe)
Tipular cheethami	Cranefly	Nationally Scarce	Flushes, moorland; larvae in wet mossy rock-faces on streams and waterfalls	North-west England to Cheshire
Tipula gimmerthali	Cranefly	RDB3	Flushes and margins of base-rich streams	Moor House, Westmorland
Triogma trisulcata	Cranefly	RDB3	Seepage bog and upland streams	Yorkshire, Lancashire
Beetles				
Elaphrus lapponicus	Ground beetle	Nationally Scarce A	Margins of swift montane streams, bogs	Yorkshire, Cumbria
Oreodytes davisii	Diving beetle	Nationally Scarce B	Shallow margins of fast streams and rivers	Yorkshire, Northumberland
Spiders				
Erigone capra	Money spider	Nationally Scarce B	In moss or grass at the edge of open water	Yorkshire, Cumbria, Northumberland
Erigone psychrophila	Money spider	Nationally Scarce A	Montane, in *Sphagnum* at the edge of bog pools	Cheviot, Northumberland
Crustacea				
Austropotamobius pallipes	White-clawed crayfish	HSD, Priority	Stony streams, rivers, lakes and large ponds	Widespread
Mysis relicta	Opossum shrimp	RDB1, SCC	Lake bottom and pelagic	Ennerdale Water
Molluscs				
Catinella arenaria	Sandbowl snail	RDB1, Priority	Base-rich flushes	Crumbria, Devon
Margaritifera margaritifera	Freshwater pearl mussel	HSD, Priority	Unpolluted, well oxygenated rivers with clean gravels	R. Ehen, Cumbria
Pisidium conventus	Pea mussel	Nationally Scarce A, SCC	Lakes and tarns	Lake District

Invertebrate species		Nature conservation status	Typical habitat	Distribution in upland England (not currently available in terms of NaturalAreas)
Scientific name	**English name**			
Pisidium tenuilineatum	Fine-lined pea mussel	RDB3, Priority	Rivers, streams, springs	Yorkshire (R. Wharfe) and lowland sites in southern England
Vertigo genesii	Round-mouthed whorl snail	RDB1, HSD, Priority	Base-rich flushes	Durham
Vertigo geyeri	Geyer's whorl snail	RDB1, HSD, Priority	Base-rich	Cumbria

Key to Table 9.9

Status

HSD	Included in the Habitats Directive
RDB1	Red Data Book category 1 Endangered
RDB2	Red Data Book category 2 Vulnerable
RDB3	Red Daa Book category 3 Rare
RDB4	Red Data Book category 4 Out of Danger
RDB5	Red Data Book category 5 Endemic
RDBI	Red Data Book category Indeterminate
RDBK	Red Data Book category Insufficiently known
Nationally Scarce A	15-30 km squares of national grid
Nationally Scarce B	30-100 km squares of national grid
Priority	Priority species in the UK Biodiversity Action Plan (UK Biodiversity Group 1998; UK Steering Group 1995)
SCC	Species of concern in the UK Biodiversity Action Plan (UK Biodiversity Group 1998; UK Steering Group 1995)

Table 9.10 Fish of conservation significance in upland freshwater habitats in England

	Biodiversity Action Plan[1]	Included in the EC Habitats Directive	Included in Schedule 5 of the W & C Act 1981
Fish			
Bullhead *Cottus gobio*	SCC	Annex IIa	-
Brook lamprey *Lampetra planeri*	SCC	Annex IIa	-
River lamprey *Lampetra fluviatilis*	SCC	Annexes IIa & Va	-
Sea lamprey *Petromyzon marinus*	SCC	Annex IIa	-
Salmon *Salmo salar*	SCC	Annexes IIa & Va (in fresh water only)	-
Allis shad *Alosa alosa*	Priority	Annexes IIa & Va	Section 9(1) & (4a) only
Twaite shad *Alosa fallax*	Priority	Annexes IIa & Va	Section (4a) only
Vendace *Coregonus albula*	Priority	Annex Va	Full protection
Schelly *Coregonus lavaretus*	SCC	Annex Va	Full protection
Arctic char *Salvelinus alpinus*	SCC	-	-
Grayling *Thymallus thymallus*	SCC	Annex Va	-

Key

1. Priority species and Species of conservation concern (SCC) from UK Steering Group 1995 and UK Biodiversity Group 1998.

Table 9.11 Conservation objectives for standing waters

Conservation objectives	Management activities likely to affect conservation objective
Restore or maintain the appropriate nutrient status.	! Run-off of fertiliser applications / slurry effluent. ! Discharge of effluent, eg sewage, fish farms. ! Domestic / industrial discharges. ! Grazing leading to local enrichment from dunging.
Improve or maintain water quality other than nutrient status.	! Accidental and deliberate discharges of oil, chemicals, eg sheep dip. ! Additions of water from different catchments. ! Activities which increase siltation, eg ploughing. ! Processes leading to acid rain.
Restore or maintain water levels and flushing rates.	! Drainage / moor gripping. ! Abstraction directly from water source or water table. ! Impoundment.
Maintain or enhance desirable marginal communities.	! Agricultural activities such as fertiliser / slurry applications, grazing / watering of stock, drainage. ! Impoundment.
Restore, maintain or enhance the naturalness of the freshwater habitats.	! Introduction of artificial edges to the water body.
Limit and, where possible, eliminate introduced species.	! Deliberate introductions, eg of fish, wildfowl, plants. ! Accidental introductions, eg from fishing gear.
Ensure land use within the catchment does not adversely affect the nature conservation value.	! Shading, eg development or planting of woodland and scrub. ! Activities which increase siltation, eg ploughing. ! Physical damage or change to the edge of water course, eg poaching, bank protection. ! Recreational pressure, especially sailing.
Prevent abnormal sediment accretion.	! Activities which increase siltation, eg ploughing, drainage.
Restore or maintain the desirable balance of plant species.	! Vegetation control methods, eg cutting, spraying.
Maintain or enhance populations of rare and scarce species.	! Many of the activities covered above, depending on the species and their requirements.

Table 9.12 Conservation objectives for running waters

Conservation objectives	**Management activities likely to affect conservation objective**
Restore or maintain the appropriate nutrient status.	! Run-off of fertiliser applications / slurry effluent. ! Discharge of effluent, eg sewage, fish farms. ! Domestic / industrial discharges. ! Grazing leading to local enrichment from dunging.
Improve or maintain water quality other than nutrient status.	! Accidental and deliberate discharges of oil, chemicals, eg sheep dip. ! Activities which increase siltation, eg ploughing. ! Additions of water from different catchments.
Restore or maintain water levels and flow regimes.	! Drainage / moor gripping / abstraction. ! Abstraction directly from water source or water table. ! Impoundment.
Maintain or enhance desirable marginal communities.	! Agricultural activities such as fertiliser / slurry applications, grazing / watering of stock, drainage. ! Impoundment.
Restore or retain the natural channel profile.	! Introduction of artificial edges to the water body, or straightening of channels.
Restore, maintain or enhance the naturalness of the freshwater habitats.	! Introduction of artificial edges or straightening of channels.
Protect associated physical features, such as meanders, cut-off channels.	! Channel straightening, flood defence measures, land reclamation.
Restore or retain optimum shading of the channel.	! Planting or growth of woodland and scrub.
Limit and, where possible, eliminate introduced species.	! Deliberate introductions, eg of fish, wildfowl. ! Accidental introductions, eg on fishing gear.
Ensure land use within the catchment does not adversely affect the nature conservation value.	! Shading, eg development or planting of woodland and scrub. ! Activities which increase siltation, eg ploughing. ! Physical damage or change to the edge of water course, eg poaching, bank protection. ! Recreational pressure, especially sailing.
Prevent abnormal sediment accretion.	! Activities which increase siltation, eg ploughing, drainage.
Restore or maintain the desirable balance of plant species.	! Vegetation control methods, eg cutting, if particular types of vegetation start to dominate.
Maintain or enhance populations of rare and scarce species.	! Many of the activities covered above, depending on the species and their requirements.

Table 9.13 Conservation objectives for swamp and fen

Conservation objectives	Management activities likely to affect conservation objective
Maintain the current extent of swamp, fen and carr.	! Drainage, cutting, burning, over-grazing.
Improve all existing areas of swamp, fen and carr habitat by appropriate management.	! Selective cutting / grazing.
Re-establish swamp, fen and carr around existing freshwater habitats.	! Impeding drainage / provide conditions for seasonal flooding.
Establish linkage between smaller areas to enhance value to wildlife.	! Creation / enhancement of habitats of value to wildlife.
Improve or maintain nutrient status and water quality.	! Liming / addition of fertilisers. ! Pollution of area. ! Run-off of fertiliser from surrounding land.
Manage water levels to ensure occasional flooding, where appropriate.	! Drainage / moor gripping / abstraction.
Ensure that marginal communities do not dry out.	! Drainage / moor gripping / abstraction.
Maintain or enhance desirable marginal communities.	! Agricultural activities such as fertiliser / slurry applications, grazing / watering of stock.
Limit and, if possible, eliminate introduced species.	! Fish farming and fishery management.
Maintain or enhance populations of rare and scarce species.	! Many of the activities covered above, depending on the species and their requirements.

Table 9.14 Habitat requirements of upland freshwater plants

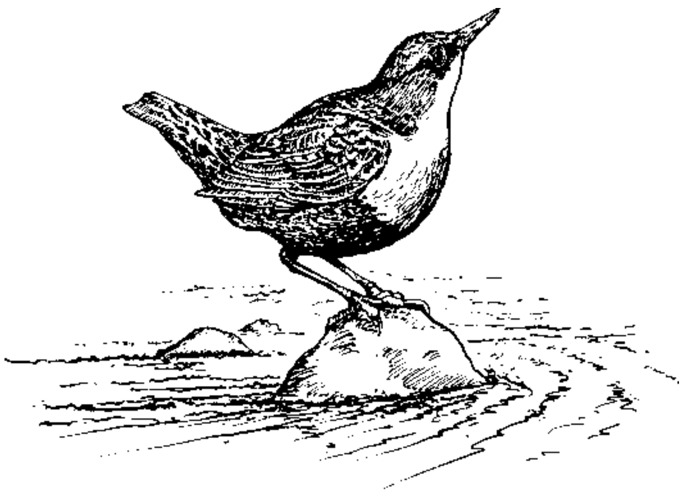
Depth requirements are measured in cm. A minus sign indicates that the water table is below ground level, the plus sign indicates water level above ground level, ie depth of water. Figures in brackets refer to extreme records where species may have been found on one or two occasions (Newbold & Mountford 1997).

Freshwater plants	Habitat requirements
Elatine hexandra	Soft, sandy mud; periodic exposure; shallow edges; can tolerate nutrient enrichment. **Depth requirements**: Preferred water level: +50 +100cm Limit of 'dryness': -150 Limit of 'wetness': +200(300) *E. hexandra* is well adapted to tolerate extremes of this range. **Preferred pH range**: pH5.5-pH6.0
Isoetes echinospora	Acid, gravelly, nutrient-poor substrate; depths to around 2 m; disturbance through wave action etc to dislodge spores. **Preferred pH range**: pH6.0 - pH7.0
Luronium natans	Slightly acidic, oligotrophic, standing waters, with depth of as much as 2 m. **Depth requirements**: Preferred water level: +10-100 Limit of 'dryness': +5 Limit of 'wetness': +150 **Preferred pH range**: pH5.5-pH7.0
Najas flexilis	Silty substrates, mesotrophic lowland lakes; grows in water more than 1.5 m deep. **Depth requirements**: Preferred water level: +50+100 Limit of 'dryness': +20 Limit of 'wetness': +150 **Preferred pH range**: pH5.5-pH6.5
Calamagrostis stricta	Neutral bogs and marshes; shallow canal edges
Eleocharis austriaca	Sandy substrate on upland river margins Depth requirements Preferred water level: -5+5
Juncus filiformis	Lake margins; marshy grassland or lake shore sand and gravel.

Table 9.15 Habitat requirements of lowland freshwater plants which occur in upland areas

Depth requirements are measured in cm. A minus sign indicates that the water table is below ground level, the plus sign indicates water level above ground level, ie depth of water. Figures in brackets refer to extreme records where species may have been found on one or two occasions (Newbold & Mountford 1997).

Fresh water plant	Habitat requirements
Potamogeton compressus	Slow-flowing lowland rivers and ox-bows; calcareous, mesotrophic lowland lakes. **Depth requirements**: Preferred water level: +10+100 cm Limit of 'dryness': (+2) Limit of 'wetness': +150
Potamogeton trichoides	Shallow, still, slow moving water; meso-eutrophic conditions; tolerated disturbance readily, eg drainage. **Depth requirements**: Preferred water level: +20+75 Limit of 'wetness': +100
Pilularia globulifera	Lowland, non-calcareous, silty or peaty standing water. **Depth requirements**: Preferred water level: +10+20 Limit of 'dryness': 0+5 Limit of 'wetness': (+75)
Carex elongata	Lowland ponds; winter flooding and drying in summer; stagnant ditches; minimal shading; undisturbed banks.
Circuta virosa	Lake shores, pond margins, mires and ditches; shallow water or vegetation mats; restricted to lowlands.
Equisetum variegatum	Open habitats; base-rich flushes.



Dipper

Table 9.16 Management prescriptions for *Luronium natans*

Habitat requirements for *L. natans*	Management prescriptions for *L. natans*
L. natans occurs naturally in upland oligotrophic lakes and lowland canals. However, it is an extremely rare species in the English uplands, with only two recent records in Derwent Water and Bassenthwaite Lake (Cumbria Fells & Dales Natural Area). This species tends to occur in oligotrophic water bodies that have undergone some disturbance, hence its success in lightly dredged canals. However, the increasing density of boat traffic on many canals has been one of the principal causes of the species' decline. The turbulence caused by intense boat activity leads to shallow rooted stolons becoming detached. Water acidification is another factor causing loss or decline of this species.	! Seek to minimise the effects of acidification on waters containing the species in acid-sensitive areas. ! Prevent the encroachment of emergent vegetation likely to out-compete this plant. ! In disused and little used canals, seek a programme of dredging and other maintenance work to produce the open habitat necessary for this plant. ! Seek to dissuade planting of coniferous forests in sensitive lake catchments and around river headwaters important for this species. ! Where high volumes of boat traffic may damage beds of this species, seek to develop 'refuges' near the banks protected by barriers such as piling. ! Where canals containing the plant are subject to unavoidable restoration schemes, consider creating reserves (either as widened areas or secondary channels or ponds) and manage them to maintain healthy populations. *L. natans* should be translocated to the reserve in advance of the restoration works. ! Where such forests already exist, encourage the creation of buffer zones around lake shores and river margins to allow deciduous woodland to develop. ! In areas with records of the species but where it is no longer apparently present, experiment with dredging small areas of water bodies to give any remaining seed a chance to germinate.

Table 9.17 Habitat requirements of birds associated with upland freshwater habitats

Species	Habitat requirements
Wigeon *Anas penelope*	See Chapter 6.
Teal *Anas crecca*	See Chapter 6.
Goosander *Mergus merganser*	! Present late February to end July. ! Strong association with rivers and lakes. ! Nests placed in holes in larger riverside trees. ! Adults and young forage for aquatic invertebrates in rivers, lakes and pools.
Osprey *Pandion haliaetus*	! Present April to September. ! Strong association with lakes and large rivers. ! Nest in trees. ! Adults bring fish to dependent young in nest.
Common sandpiper *Actitus hypoleucos*	! Present late April to end July. ! Strong association with shallow, swift-flowing rivers and reservoir sides with exposed substrates. ! Nest placed on ground within stream or lake-side heather, bracken or grass tussocks, appears to avoid areas regularly used by anglers and others engaged in waterside recreation. ! Adults forage for aquatic and aerial invertebrates amongst exposed gravels along stream and lake-sides and amongst wet and exposed riparian zone for invertebrates. ! Chicks forage for invertebrates as adults.
Black-headed gull *Larus ridibundus*	See Chapter 6.
Common gull *Larus canus*	See Chapter 6.
Grey wagtail *Motacilla cinerea*	! Present throughout the year. ! Strong association with upland streams and rivers, lake shores and other fresh waters. ! Nest placed under rock overhang, tree root or bridge, usually in association with streams, rivers or lake shores. ! Adults forage for terrestrial invertebrates along stream sides, exposed lake shore and riparian grasslands and around outbuildings. ! Adults bring food to dependent young in nest.
Dipper *Cinclus cinclus*	! Present throughout the year. ! Strong association with riffle zone of calcareous to circumneutral upland streams. ! Extremely susceptible to acidification - favoured mayfly larvae food does not survive acid conditions. ! Nest placed beneath bridge or other overhang in stream or, less commonly, at lake sides. ! Adults take aquatic invertebrates from riffles along mountain streams and lake shores. ! Adults bring food to dependent young in nest.

Table 9.18 Management guidelines for birds associated with upland freshwater habitats

Running water	Standing water	Surrounding land
! Retain and enhance the naturalness of running waters and fringing habitats. ! Maintain water quality. ! Maintain water levels and flow regimes. ! Retain or re-establish natural channel profile. ! Retain or re-establish features such as meanders, bluffs, channels and flood plains. ! Retain or re-establish native bank side vegetation. ! Establish areas that are not disturbed by recreation (boats, anglers, walkers).	! Retain and enhance the naturalness of standing waters and fringing habitats. ! Maintain water quality. ! Maintain water levels. ! Retain or re-establish natural shore profile. ! Retain or re-establish swamp, fen and carr. ! Establish areas that are not disturbed by recreation (boats, anglers, walkers).	! Prevent deterioration of water quality because of eutrophication, siltation, toxic contaminants, etc. ! Prevent deterioration of quality of fringing habitats because of grazing, etc. ! Prevent reduction in water levels because of over abstraction, etc. ! Maintain natural drainage systems and avoid new drainage. ! Retain wetland features such as pools, fens and mires. ! Create small, wet areas by blocking existing drains and grips. ! See Chapters 6 & 7 for further details.

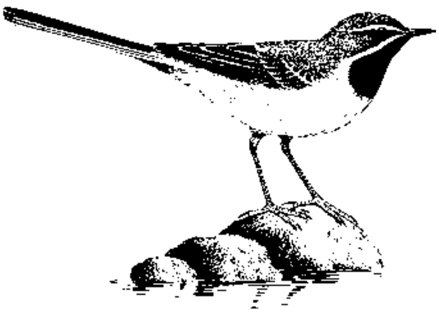


Table 9.19 Habitat management requirements of invertebrates associated with upland freshwater habitats in England

As many of these habitats are not man-made or dependent upon traditional land use for their continued existence, most of the management recommendations are necessarily phrased in negative terms, since non-intervention is the most beneficial management.

Freshwater invertebrates	Habitat requirements	Management requirements
Freshwater pearl mussel *Margaritifera margaritifera*	Clear, cool, fast-flowing, unpolluted, acid waters that are well oxygenated and low in nutrients. Require fish host for parasitic phase. Also mosaic of habitat for feeding and shelter, and clean gravels for reproducing.	! Avoid enrichment by point and diffuse sources of pollution. ! Retain overhanging trees, undercut banks for shade. ! Maintain healthy fish stocks. ! Ensure sheep dips used in accordance with good practice and not disposed on rivers. ! Avoid physical alteration of river course.
White-clawed crayfish *Austropotamobius pallipes*	Unpolluted, calcium-rich water with high levels of oxygen and low siltation levels. Also mosaic of habitats for feeding and shelter, including gravels, tree roots, stone walls, bridges, etc.	! Avoid input of silt. ! Maintain diversity of physical habitat in particular bank structure.
Species of open flushes	Mainly sunny, well-lit trickles that can warm up. Not too much overgrowth of tall grasses or thatch of litter. Isolated scrub (especially sallow). Permanent water supply (no summer drought). Even small flushes can support good assemblages, provided they are permanent. Calcareous seepages support more scarce species than neutral or acid ones. Flowering plants to provide nectar and pollen sources.	! Maintain light grazing and very light trampling. ! Prevent drainage or water abstraction from springs. ! Keep scrub to a small proportion of the site, with only a small amount over shading the trickles.
Species of carr woodland	High humidity. Deep organic soil that is permanently saturated to ground level. Seepages and shallow pools. Old trees and dead wood.	! Avoid gaps in the canopy, coppicing or rides. ! Prevent drainage.
Species of small pools.	Various - see Kirby 1992.	! As specified in Kirby 1992.
Species of small fast streams	Leaf litter input from overhanging vegetation (trees, grasses, etc).	! Avoid intensive grazing which reduces the potential for litter input.

Freshwater invertebrates	Habitat requirements	Management requirements
Aquatic species of larger streams and rivers	Natural pool and riffle to provide contrasting conditions of current. Marginal emergents (eg *Phalaris*) along some sections as shelter for adults of species with aquatic larvae (eg mayflies, stoneflies, caddis). Intermittently spaced trees, especially alder, to provide shelter, submerged roots as underwater shelter, and coarse woody debris (important food source). No unnatural silt load.	! Prevent river canalisation or artificial steepening of banks. ! Limit forestry operations that increase silt loads. ! Maintain some trees along the banks.
Terrestrial species of vegetated margins of unshaded larger streams and rivers.	Vegetation mosaic with margins having mostly tall plants and a smaller proportion of short to bare vegetation. Limited shading by tree with some litter input from leaf-fall. Accumulations of pockets of leaf litter and strand lines. Flowering plants to provide nectar and pollen sources.	! At most, maintain light grazing and trampling, and preferably none. ! Fence fields with heavy grazing pressure.
Species of exposed riverine sediments (gravel beds)	Natural flow regime that allows the development and annual redistribution of gravels and stones, and natural erosion of river banks to provide this material. Bars of sediments with a range of particle sizes from large stones to sand. Absence of colonisation by vegetation on exposed sediments.	! Prevent trampling by livestock, by fencing sections with large sediment banks. ! Avoid gravel winning, impoundments or bank stabilisation.
Aquatic species of tarn and lake shores	Shelter above and below water, and provision of litter (food supply) by a dense fringing stands of emergent vegetation (eg reeds *Phalaris*), or trees lining the shore. Some areas of wave-washed stony shore. Dense submerged aquatic plants that provide refuge from fish predation.	! Ensure minimal destruction of the marginal vegetation (eg no burning from camp fires, or excessive trampling). ! Fish stocking should be at no more than the natural carrying capacity of the water body.
Terrestrial species of tarn and lake shores	Similar to above. Accumulations of pockets of leaf litter and strand lines. Partial natural drop in water level in summer to expose a bare shoreline.	! Leave plant litter, avoid tidying up. ! Ensure minimal trampling of shoreline gravels.

Table 9.20 Habitat and management requirements of certain mammals, amphibians and reptiles associated with upland freshwater habitats[1]

Species	Habitat requirements	Management requirements in freshwater habitats
Otter *Lutra lutra*	Large home ranges (perhaps 10's of km across); therefore need for large / inter-connected habitats. Dependent on water (which can be fresh, estuarine or marine); requires good water quality and presence of animal (fish, some invertebrates, eg crayfish) food. It is vulnerable to disturbance, pollution or river management. Requires secure lying-up (eg wet woodland carr) and breeding sites (often associated with riverside trees, particularly mature oak, ash and sycamore) and their availability may influence distribution.	! Ensure good water quality, unaffected by pollution, pesticides and fertilisers, to maintain fish prey species and prevent accumulations of toxins. ! Manage river sides to ensure a range of habitats extending back from the river margin, and with a good vegetation structure up to the river edge. ! Allow vegetation to grow along river and canal banks. ! Maintain existing fens, wet woodland and carr vegetation for holts and lying up areas. ! Encourage or create fens where appropriate. ! Ensure river engineering is sensitive when regrading banks, straightening rivers or devising erosion control methods. ! Ensure connectivity of habitats over the large home ranges, eg maintain or create linear features to connect different areas. ! Ensure infrastructure projects, eg road building, are designed to maintain connections between habitats, eg via wildlife tunnels or bridges. ! See Species Action Plan (UK Steering Group 1995).
Water vole *Arvicola terrestris*	Steep banks; high vegetational structural diversity; absence of mink or extensive width of marginal vegetation	! Ensure good water quality, unaffected by pollution, pesticides and fertilisers, to prevent direct toxicity. ! Manage river sides to ensure a range of habitats extending back from the river margin. ! Allow vegetation to grow along river and canal banks. ! Ensure river engineering is sensitive when regrading banks, straightening rivers or devising erosion control methods. ! Encourage fen habitats, the larger the better. ! Ensure connectivity of habitats, eg maintain or create features such as hedgerows, marshes and woodland margins, to connect different areas. ! Ensure infrastructure projects, eg road building, are designed to maintain connections between habitats, eg via wildlife tunnels or bridges. ! See Species Action Plan (UK Steering Group 1995).

Species	Habitat requirements	Management requirements in freshwater habitats
Water shrew *Neomys fodiens*	Unknown; while often associated with clear, fast-flowing, unpolluted water are also found by ponds and drainage ditches, rocky beaches and even some distance from water; linear features such as hedges valuable for connecting populations.	! Ensure good water quality, unaffected by pollution, pesticides and fertilisers, to maintain invertebrate prey species and prevent direct toxicity. ! Maintain existing fens, wet woodland, carr vegetation and small water bodies such as ponds, streams and ditches. Encourage or create them where appropriate.
Great crested newt *Triturus cristatus*	Unshaded, fish-free ponds; generally between 100 - 300 m^2 in surface area with depths around 1-2 m maximum, with good cover of aquatic and emergent vegetation. Associated with these is a structurally diverse terrestrial habitat which may be grasses, hedgerows, woodland or even open or well grazed land provided that the ground itself is deeply fissured and has a range of invertebrate species for prey. Structures, such as log piles, for hibernation are required.	! Maintain and create appropriate pond habitats for breeding, with suitable surrounding terrestrial habitat. ! Create small clusters of ponds in different locations; pond clusters (more than two ponds within a few hundred metres of each other) are preferable for safeguarding amphibian populations than single, isolated ponds. ! Ensure connectivity between populations, by maintaining or providing suitable terrestrial habitat between ponds and pond clusters. ! Do not drain wetlands. ! Ensure good water quality, unaffected by pollution, pesticides and fertilisers, to maintain populations and their invertebrate prey species. ! Fish eat newt larvae and may need to be removed from ponds which are permanent, but the Environment Agency must be consulted and a licence obtained to do this. ! See Species Action Plan (UK Steering Group 1995).
Natterjack toad *Bufo calamita*	Shallow, often ephemeral ponds, that hold water between April and late July. Generally these are relatively free of weed. Terrestrial habitat associated with this is often fairly open in structure with very short turf (eg close-grazed by sheep or rabbits) or bare ground over which the animals actively forage. Structures, such as log piles, for hibernation or a sandy soil or soft rock substrate in which to burrow are required.	! Maintain and create appropriate pond habitats for breeding, with suitable surrounding terrestrial habitat. ! Create small clusters of ponds in different locations; pond clusters (more than two ponds within a few hundred metres of each other) are preferable for safeguarding amphibian populations than single, isolated ponds. ! Ensure connectivity between populations, by maintaining or providing suitable terrestrial habitat between ponds and pond clusters. ! Do not drain wetlands where they occur. ! Ensure good water quality, unaffected by pollution, pesticides and fertilisers, to maintain populations and invertebrate prey species. ! See Species Action Plan (UK Steering Group 1995).

Species	Habitat requirements	Management requirements in freshwater habitats
Grass snake *Natrix natrix*	Structurally diverse, but generally open vegetation, such as open grassland (with no or very low grazing levels), open woodlands / woodland rides, hedgerows; that offer a range of different 'thermal' environments during the day. Banks and slopes are especially favoured. Egg laying sites of rotting vegetation, compost heaps, piles of wood chips, manure piles are important for breeding. Structures, such as log piles, banks, cracked ground are required for hibernation and as lying up areas over night and during extremes of temperature.	! Maintain and create pond habitats for amphibians and fish for feeding. ! Create small clusters of ponds in different locations; pond clusters (more than 2 ponds within a few hundred metres of each other) are preferable for safeguarding amphibian populations than single, isolated ponds. ! Ensure connectivity between amphibian and snake populations, by maintaining or providing suitable terrestrial habitat between ponds and pond clusters. ! Promote the conservation of grass snakes in areas with good populations of amphibians (where this does not jeopardise any over-riding conservation interests, eg natterjack toad conservation). ! Ensure good water quality, unaffected by pollution and pesticides, to maintain their amphibian and fish prey species. ! Do not drain wetlands.

Key

1. Arnold 1995; Beebee 1996; Harris *et al* 1995; Hilton-Brown & Oldham 1991; Morris 1993; Swan & Oldham 1993a & b.

Table 9.21 Habitat and management requirements of fish of conservation significance in upland freshwater habitats in England

Species	Habitat requirements	Management requirements
Bullhead *Cottus gobio*	! Clean gravels. ! Fast flowing clean water.	! Maintain water quality particularly oxygen. ! Limit, nutrients and siltation. ! Avoid habitat modification. ! Maintain bank structure.
Salmon *Salmo salar* / sea trout / brown trout adults	! Deep water with plenty of cover such as undercut banks, overhanging vegetation, weed or rock to lie up in.	! Maintain access up through the catchment to spawning beds. ! Avoid obstructions and where obstructions occur incorporate appropriate fish passes.
spawners	! Clean gravels with low levels of silt and well oxygenated unpolluted water.	! Maintain water quality, particularly oxygen and nutrients. ! Limit siltation.
fry	! Bank side cover, good supply of food.	! Avoid insensitive habitat modification which removes mosaic of pools and riffles.
parr	! Fast riffles and runs. ! Plenty of cover such as weeds, rocks, banks. ! Cool clean well oxygenated water.	! Maintain bank structure, overhanging trees, scrubs. ! Maintain river flows and spates.
Grayling *Thymallus thymallus* spawners	! Clean gravel.	! Maintain water quality, particularly oxygen and nutrients. ! Limit siltation.
juveniles	! Shallow flowing water.	! Avoid habitat modification.
adults	! Deeper water in glides.	
Lampreys *Lampetra* spp and *Petromipon marinus* spawners	! Clean gravels, fast flows.	! Maintain mosaic of habitats. ! Ensure gravels do not become silted.
juveniles	! Silts or fine sands with low organic matter for ammocoete larvae to bury in.	! Avoid total removal of silt beds. ! Maintain bank structure. ! Maintain access through estuaries. ! Avoid obstructions, incorporate appropriate fish passes where obstructions occur.

Species	Habitat requirements	Management requirements
Vendace *Coregonus albula* and schelly *Coregonus lavaretus*		
spawners	! Clean littoral gravels for spawning	
juveniles and adults	! Deep nutrient poor lakes. ! High levels of oxygen.	! Maintain good water quality in particular reduce enrichment, maintain high levels of oxygen. ! Maintain gravels free of silt. ! Avoid fluctuating water levels which can leave littoral spawning beds stranded. ! See Vendace Species Action Plan (UK Steering Group 1995).
Allis shad *Alosa alosa* Twaite shad *Alosa fallax*	! Clean gravels adjacent to deep pools for spawning.	! Maintain gravel shoals and deep pools in areas where fish spawn. ! Maintain water quality, in particular oxygen levels with special emphasis on estuaries. ! Maintain flows during migration period (April to August). ! Do not obstruct migration route and where possible remove or modify existing obstructions. ! See Species Action Plan (UK Steering Group 1995).