Ecology of Watercourses Characterised by *Ranunculion fluitantis* and *Callitricho-Batrachion* Vegetation

Conserving Natura 2000 Rivers

Ecology Series No. 11

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This document was produced with the support of the European Commission's LIFE Nature programme. It was published by **Life in UK Rivers**, a joint venture involving English Nature (EN), the Countryside Council for Wales (CCW), the Environment Agency (EA), the Scottish Environment Protection Agency (SEPA), Scottish Natural Heritage (SNH), and the Scotland and Northern Ireland Forum for Environmental Research (SNIFFER).

ISBN 1 85716 723 6

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This document should be cited as: Hatton-Ellis TW & Grieve N (2003). *Ecology of Watercourses Characterised by* Ranunculion fluitantis *and* Callitricho-Batrachion *Vegetation.* Conserving Natura 2000 Rivers Ecology Series No. 11. English Nature, Peterborough.

Technical Editor: Lynn Parr
Series Ecological Coordinator: Ann Skinner

Cover design: Coral Design Management, Peterborough.
Printed by Astron Document Services, Norwich, on Revive, 75% recycled post-consumer waste paper, Elemental Chlorine Free. 1M.

Cover photo: Nigel Holmes

Conserving Natura 2000 Rivers

This account of the ecological requirements of watercourses characterised by *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation has been produced as part of **Life in UK Rivers** – a project to develop methods for conserving the wildlife and habitats of rivers within the Natura 2000 network of protected European sites. The project's focus has been the conservation of rivers identified as Special Areas of Conservation (SACs) and of relevant habitats and species listed in annexes I and II of the European Union Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC) (the Habitats Directive).

One of the main products is a set of reports collating the best available information on the ecological requirements of each species and habitat, while a complementary series contains advice on monitoring and assessment techniques. Each report has been compiled by ecologists who are studying these species and habitats in the UK, and has been subject to peer review, including scrutiny by a Technical Advisory Group established by the project partners. In the case of the monitoring techniques, further refinement has been accomplished by field-testing and by workshops involving experts and conservation practitioners.

Life in UK Rivers is very much a demonstration project, and although the reports have no official status in the implementation of the directive, they are intended as a helpful source of information for organisations trying to set 'conservation objectives' and to monitor for 'favourable conservation status' for these habitats and species. They can also be used to help assess plans and projects affecting Natura 2000 sites, as required by Article 6.3 of the directive.

As part of the project, conservation strategies have been produced for seven different SAC rivers in the UK. In these, you can see how the statutory conservation and environment agencies have developed objectives for the conservation of the habitats and species, and drawn up action plans with their local partners for achieving 'favourable conservation status'.

Understanding the ecological requirements of river plants and animals is a prerequisite for setting conservation objectives, and for generating conservation strategies for SAC rivers under Article 6.1 of the European Habitats Directive. Thus, the questions these ecology reports try to answer include:

- What water quality does the species need to survive and reproduce successfully?
- Are there other physical conditions, such as substrate or flow, that favour these species or cause them to decline?
- What is the extent of interdependence with other species for food or breeding success?

For each of the 13 riverine species and for the *Ranunculus* habitat, the project has also published tables setting out what can be considered as 'favourable condition' for attributes such as water quality and nutrient levels, flow conditions, river channel and riparian habitat, substrate, access for migratory fish, and level of disturbance. 'Favourable condition' is taken to be the status required of Annex I habitats and Annex II species on each Natura 2000 site to contribute adequately to 'favourable conservation status' across their natural range.

Titles in the Conserving Natura 2000 Rivers ecology and monitoring series are listed inside the back cover of this report, and copies of these, together with other project publications, are available via the project website: www.riverlife.org.uk.

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Introduction

Watercourses characterised by submerged or floating-leaved vegetation form a priority habitat of international importance, and are listed on Annex II of the Habitats Directive. The riverine plant communities occurring in the UK are important in a European context (Mainstone 1999), and provide good examples of the range of river types and variability of associated plant communities.

Semi-natural watercourses are dynamic habitats, subject to many influences that can act alone or in combination to affect the distribution, composition and abundance of associated plant communities. Such rivers are intimately connected to floodplain habitats and function as important wildlife corridors, connecting otherwise isolated or fragmented habitats in the wider countryside. Aquatic plant communities comprise a significant component of the physical and biological diversity, habitat structure and ecology of river channels, providing habitat and food for a range of species, particularly invertebrates and fish. Aquatic plants also influence and modify flow, nutrient and sediment dynamics.

Tristan Hatton-Ellis/CCW

Aquatic plant communities, such as beds of *Ranunculus* species, play a significant part in the ecology and diversity of watercourses, prodiving habitat and food, and modifying river dynamics.

Concern has been increasing about recent declines in macrophyte diversity in European rivers (Wiegleb *et al*. 1991; Dawson & Newman 1999; WWF 1999; Environment Agency undated). This has been attributed to a number of interrelated factors, including nutrient enrichment, siltation, low flows arising from drought and over-abstraction of groundwater, and unsuitable management practices. Consequently, there has been a rapid decline of many of the plant species associated with this habitat, including *Potamogeton* spp. (Wiegleb *et al*. 1991), *Groenlandia densa*, *Oenanthe fluviatilis* (Preston & Croft 1997) and *Ranunculus fluitans* (Cook 1966).

The definition of watercourses characterised by *Ranunculion fluitantis* and *Callitricho-Batrachion* (CB) communities is very wide, in practice covering the majority of rivers and streams with aquatic plant communities of note. This is reflected in the wide range of rivers in the UK that have been proposed for designation as Special Areas of Conservation (SACs) for this feature (Table 1).

This report defines the habitat and presents an initial classification system for its characteristic macrophyte assemblages, with information on associated habitat, impacts and management. This is

Table 1. River SACs in the UK designated for the watercourses of plain, submontane levels characterised by *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation.

Wales	Afon Gwyrfai & Llyn Cwellyn	Gwynedd
Wales	Afon Teifi	Ceredigion/Pembrokeshire
Wales	Afonnydd Cleddau	Pembrokeshire
Northern Ireland	Cladagh	Fermanagh
Northern Ireland	Foyle	Tyrone/Londonderry
Northern Ireland	Owenkillew	Tyrone
England	River Axe	Devon / Dorset
England	River Avon (Hampshire)	Hampshire
England	River Eden	Cumbria
Wales / England	River Dee & Llyn Tegid	Gwynedd/Conwy/Denbighshire/Wrexham /Cheshire
England	River Derwent (Yorkshire)	Yorkshire
England	River Itchen	Hampshire
England	River Kent	Cumbria
England	River Lambourn	Hampshire/Dorset
England	River Mease	Lincolnshire/Shropshire
England / Scotland	River Tweed	Northumberland/Roxburgh/Selkirkshire
Wales	River Usk	Powys/Monmouthshire/Newport
England	River Wensum	Norfolk
Wales / England	River Wye	Powys/Herefordshire/Monmouthshire
Northern Ireland	Upper Ballinderry	Tyrone

considered necessary because the feature as defined is too broad for a single set of conservation guidelines to cover it. For example, upland sites on acidic geology may be primarily threatened by sheep grazing and acid deposition, whereas lowland sites may be much more prone to eutrophication and abstraction. This is dealt with in detail in the next three sections.

The composition and condition of macrophyte communities can be useful for monitoring the health of a river ecosystem and interpreting the main impacts. When considering rehabilitation, an understanding of natural river dynamics and geomorphology is essential.

Vegetation community structure in a conservation context

The definition of riverine plant assemblages has always been problematic. The description of plant communities typically seeks to define them with reference to geographical or environmental gradients. More than many other habitats, river plant communities are in constant flux, with physical disturbance resulting in short-term interactions, and cycles (see Haslam 1978 for several examples). These seasonal and successional effects often mask wider-scale ecological patterns and make reliable identification of distinct communities difficult.

Consequently, phytosociology is not widely employed in British aquatic systems. Since aquatic plant associations tend to vary according to many factors, it is not usually possible to transpose central European phytosociological classifications, such as that of Ellenberg (1978), to British floras. The only serious attempt to do this was carried out by Rodwell *et al*. (1995). However, their classification is not applicable on a UK scale because it has a large number of geographical and ecological gaps.

The Interpretation Manual (EUR15), compiled to assist member countries to identify habitats listed in the Habitats Directive, describes running water as:

Sections of water courses with natural or semi-natural dynamics (minor, average and major beds) where the water quality shows no significant deterioration.

The original definition of Habitat 3260 was based on the CORINE classification system (EEC1991). This has now been replaced with the EUNIS system (Council Directive 97/62/EC) as:

Water courses of plain to montane levels, with submerged or floating vegetation of the *Ranunculion fluitantis* and *Callitricho-Batrachion* (low water level during summer) or aquatic mosses (Habitat 3260).

The EUNIS habitat classification was developed to facilitate harmonised description and collation of data across Europe, and builds on the original CORINE and Palaearctic Habitat Classifications. The EUNIS website [http://mrw.wallonie.be] describes how the various habitat codes and definitions relate between classifications.

EUNIS guidance lists the plants associated with Habitat 3260 as:

Ranunculus saniculifolius, *R. trichophyllus*, *R. fluitans*, *R. peltatus*, *R. penicillatus* ssp. *penicillatus*, *R. penicillatus* spp. *pseudofluitans*, *R. aquatilis*, *Myriophyllum* spp., *Callitriche* spp., *Sium erectum* (*Berula erecta*), *Zannichellia palustris*, *Potamogeton* spp. and *Fontinalis antipyretica*.

Habitat 3260 therefore represents a wide range of flowing waters and is based upon a phytosociological description that reflects the categorisation of *Ranunculus* species and plant communities in the European mainland (Wiegleb & Herr 1985, Haslam 1987). Emphasis is placed on *Ranunculus* species in the description, with a list of seven species and subspecies. In contrast, other genera are simply listed generically, for example, *Callitriche* spp. This may partly reflect the specific conservation importance attached to riverine *Ranunculus* species, which are widely perceived as being in decline in UK rivers (Dawson & Newman 1999; NTH Holmes, pers. com.). This, and the phrase '*Ranunculion fluitantis*' in the name has led to this habitat being commonly referred to as '*Ranunculus* rivers', and even to a perception that only *Ranunculus* species are important in the habitat.

However, more detailed examination indicates that a wider interpretation of the habitat is necessary. Phytosociological evidence (for example, see the classification and discussion in Rodwell *et al*. 1995) indicates that a wide range of species may be involved, and that the *Callitricho-Batrachion* community is 'most characteristic of fast to very swift, often spatey waters in small sandy or gravelly streams (Rodwell *et al*. 1995). Other genera, such as *Potamogeton*, also have species that are rare and declining in aquatic habitats, including rivers (see Preston & Croft 1997).

Unlike other aquatic genera, *Ranunculus* is a large and diverse genus that includes many terrestrial herbs. Even the characteristic subgenus *Batrachium* includes a number of species not normally found in rivers (for example, *R. baudotii*, a saline lagoon species, or *R. tripartitus*, which occurs in temporary ponds). Furthermore, weed cutting may have artificially enhanced many *Ranunculus* populations by removing competing species (see Ecological Impacts, p. 47). Thus, although *Ranunculus* spp. may be an important and often dominant component of this vegetation type, the heavy emphasis on this genus is not necessarily representative of the habitat as a whole.

Previous UK classification systems (Dawson & Szoszkiewicz 1999, Rodwell 1995) do not provide complete coverage of Habitat 3260. Apart from the usual problem of sampling sufficient sites, there are several reasons for this. The description of river macrophyte communities is extremely problematic, because these are comparatively species-poor systems consisting of a range of clonal species growing patchily in a complex, disturbed habitat. This makes community description extremely sensitive to patch scale. In Europe, *Ranunculus* communities are considered highly mixed and variable in species composition (Wiegleb & Herr 1985), and individual species may have different ecological requirements and habitat tolerances in different countries. Haslam (1987) describes plant communities for rivers in the European Union and illustrates how these differ between countries.

In this publication we have taken the approach of classifying entire (500 m) river sections, rather than identifying individual communities within these sections. This is because many 'communities' identified at a smaller scale are in fact patches of individual species (see Rodwell *et al*. 1995, for example), so that the principal aim of phytosociology, the simplification of complex patterns, is not achieved. Although riverine plants are not particularly easy to categorize in communities, it is possible to classify distinct community groups in the UK that have a recognised distribution depending upon geology, river type and ecological requirements of the plants (Haslam 1978, Spink *et al*. 1997). The data used to determine and describe UK river types and CB communities in a standardised manner were obtained from the JNCC (Joint Nature Conservation Committee) Rivers Database (Holmes *et al*. 1999a).

Characterisation of CB communities in UK rivers

The UK is geologically diverse and the range of river types present reflects this (Raven *et al*. 1998, Holmes *et al*. 1999a). Holmes *et al*. (1999a) compiled a large database of UK macrophyte communities, surveyed at a reach scale (0.5 km), and classified these using TWINSPAN. They highlighted geology, altitude and gradient as important features separating the main types, which are then described on the basis of their plant communities. Although the communities defined by Holmes *et al*. (1999a) are a useful description of the overall character of UK rivers, they are unsuitable for identification and characterisation of *Ranunculion fluitantis* and *Callitricho-Batrachion* communities, because:

- The river communities identified do not always correlate with the distribution of aquatic species. Terrestrial or mire species were also included in the survey and these often have a large impact on the final community.
- There is no means of identifying which sites within any given type contain *Ranunculion fluitantis/Callitricho-Batrachion* communities.

Work has recently been undertaken to provide an interpretation of the JNCC River Community Types as characterised by *Ranunculion fluitantis* and *Callitricho-Batrachion* (CB) vegetation, based on analysis of the JNCC Rivers database (TW Hatton-Ellis, in prep). This uses a slightly different approach to that of Holmes *et al*. (1999a). Using the EUNIS guidance, key taxa for defining the habitat were subdivided into seven main vegetation groups (see Appendix A), reflecting a combination of the taxa identified in the directive and ecological components of a healthy aquatic plant community. These are here termed 'vegetation components' (the term guilds is probably inappropriate due to the strong taxonomic bias) and are listed in Table 2.

Table 2. Summary of vegetation components in CB vegetation (see also Appendix A).

Crowfoots	Selected batrachian *Ranunculus* spp.
Starworts	All *Callitriche* spp.
Pondweeds	All *Potamogeton* spp., plus *Groenlandia* and *Zannichellia* spp.
Milfoils	*Myriophyllum* spp.
Bryophytes	A selection of important mosses and liverworts characteristic of rivers, including *Fontinalis* spp.
Emergents	Selected emergents closely associated with the above vegetation
Other aquatics	Mainly submerged and floating-leaved species commonly occuring in rivers

Six different communities have been provisionally identified (CB1–CB6), and Table 3 shows their occurrence in relation to the River Types defined by Holmes *et al*. (1999a). Type IV sites have been excluded from the survey as these are impacted rivers (Holmes *et al*. 1999a). The analysis did not include data from Northern Ireland, as neither *Callitriche* nor *Ranunculus* spp. were identified to species.

CB plant communities occur in a wide range of UK river types (Table 3) and provisional descriptions are given below, with reference to characteristic species composition. Maps showing their distribution have been produced from the JNCC Rivers Database. This work is designed to assist with the process of describing differences between macrophyte assemblages in a river, identifying key species of conservation interest and **possible** indicators of favourable or unfavourable condition. It will also help to factor out the effects of variables such as stream power and geology when assessing conservation status at a site level.

Table 3. ***Ranunculion fluitantis*** **and** ***Callitricho-Batrachion*** **communities related to JNCC River Community Subtype.**

JNCC subtype	CB1	CB2	CB3	CB4	CB5	CB6A	CB6B	qualifying CB Sites	in JNCC subtype	subtype qualifying as CB
Ia	17							17	18	94
Ib	21	1						22	23	96
Ic	44	12						56	58	97
IIa	36	6	2					44	54	81
IIb	44	9	14	3				70	71	99
IIc	18	4	1	1				24	39	62
IIIa		19						19	19	100
IIIb	3	52	6	4				65	71	92
IVa	4	30	5	5				44	86	51
IVb		8	1	1				10	17	59
IVc		1	1	2				4	16	25
Va				6				6	45	13
Vb		9	7	20				36	69	52
Vc		2		5	1			8	24	33
Vd				4	14			18	26	69
Ve	1			1	9			11	31	35
VIa			27	5				32	32	100
VIb			23	6				29	29	100
VIc			6	15	21			42	68	62
VId		1		19	23			43	53	81
VIe				6				6	20	30
VIIa				4	4			8	13	62
VIIb				1	1			2	23	9
VIIc		1		4	3	2		10	18	56
VIId				2	17			19	22	86
VIIIa					2			2	36	6
VIIIb					34			34	73	47
VIIIc					8			8	44	18
VIIId					26	1	4	31	39	79
VIIIe				1	15			16	55	29
IXa		3		6			1	10	19	53
IXb						18	2	20	25	80
IXc				2	5	20	7	34	46	74
Xa					9	4	26	39	75	52
Xb					1		5	6	22	27
Xc						2	1	3	48	6
Xd						3	4	7	30	23
Xe					4	1	18	23	52	44
All	188	158	93	123	197	51	68	878	1509	58

The abundance and diversity of component plants in a macrophyte community can indicate 'condition' by comparing the number of species and representativeness observed against that expected to be present in a high quality site for a particular river type (reference site). Indicator species will provide useful information regarding the type of impacts and causes of unfavourable condition (Haslam 1978, 1998).

Callitricho-Batrachion communities

The descriptions below summarise the communities identified by TWINSPAN. For each community, they indicate species most often dominant in each of the seven vegetation components, and species commonly associated with them. Note that not all species need to be present for a site to fall into a particular type.

A guideline number of vegetation components per 500 m site is also shown. Since different taxa are sensitive to different impacts, a larger number of taxa tends to reflect lower impact and/or increased habitat diversity. Although some upland habitats may naturally contain very few macrophyte species, these sites are generally considered not to qualify as *Callitricho-Batrachion* or *Ranunculion fluitantis* habitat.

An attempt has also been made to identify indicators of change by type.

- Sensitive species – those likely to be lost following ecological damage or disturbance are indicated by *.
- Opportunist species likely to increase following disturbance are indicated by $. These species may be characteristic of the community and are not in themselves indicative of poor condition. However, sections containing only these species, or extensive cover of these species, should be viewed as potentially impacted.

Applicability outside the UK

This work has been carried out using only British data, largely because this was the only dataset available with a reasonable spread of sites. It is hoped that this classification provides further insights into what is undoubtedly a difficult community to describe and classify throughout Europe. Many of the above communities will no doubt be recognisable to aquatic botanists in Europe, though there will also be differences in detail. Some reasons for this may include:

- Individual species are missing (for example, *Callitriche cophocarpa* and *Ranunculus saniculifolius* do not occur in Britain).
- The same species has different habitat preferences (for example, *Ranunculus penicillatus* ssp. *penicillatus* occurs only in rather base-poor water in Britain, whereas in Ireland it is virtually ubiquitous).
- A specific physical habitat is absent from Britain (for example, (snowmelt-influenced rivers).

These issues notwithstanding, it is hoped that this classification can provide a broad framework until more detailed analysis is available from other member states. Comparison with descriptions provided by Haslam (1987) for European vegetation communities suggests that many of these types may approximate quite well to vegetation communities elsewhere in Europe. However, some British communities are likely to be relatively impoverished in comparison to European sites, especially lowland rivers. Some types found in Europe may be absent altogether from Britain (see Haslam 1987). In contrast, some British sites may have a higher diversity than is typical in Europe, especially with respect to bryophytes.

Peter Hayes

Casting on the River Till, a tributary of the Avon, amid a bed of flowering *Ranunculus* species.

CB1: Lowland, low-gradient *Potamogeton/Sagittaria* eutrophic river community

This vegetation type typically occurs on large, slow flowing lowland rivers with a stable base flow and a substrate consisting mainly of silts or clays. *Potamogeton* spp. and *Myriophyllum spicatum* are particularly prominent within the plant community, while *Ranunculus* species are less noticeable than in many other CB types.

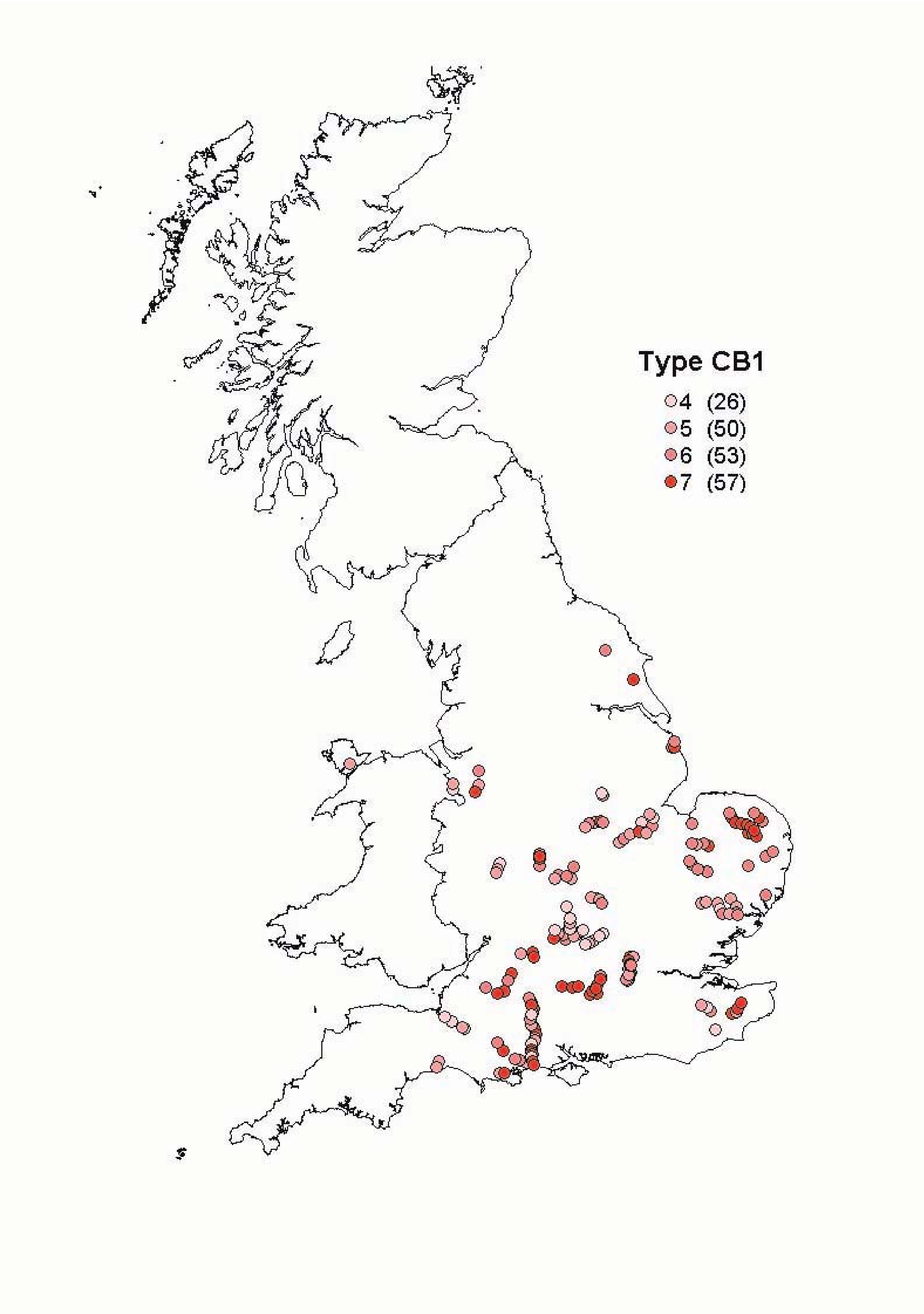
The community is mainly restricted to southern and eastern Britain, and is rarely found north of the Humber or west of the Severn Estuary. The best examples are found in Type Ia (for example, lower sections of the Hampshire Avon and River Wensum cSACs, and tributaries of the Thames such as the Loddon and Cherwell). *Ranunculus* spp. are often not particularly prominent, but its presence may be important in this type. Crowfoots are more sensitive to habitat modification, eutrophication and changes in flow regime than many other species in this community.

CB1 communities are at risk from human impacts, including river engineering, flow regulation and introduced species. Many sites show evidence of eutrophication, expressed by fewer species and increasing dominance of *Potamogeton pectinatus*. It is likely that no truly natural examples of this habitat type remain in Britain, though many sites are nonetheless of high conservation value.

CB1 rivers coincide strongly with Type I and to a lesser extent, Type II rivers of Holmes *et al*. (1999a). The best examples are semi-natural, slow-flowing reaches of base-rich rivers with stable flows, generally over an alluvial or clay substrate. Rather surprisingly, there is no clear equivalent of this community in Rodwell *et al*. (1995).

Nigel Holmes

Type CB1 typically occurs on large, slow flowing lowland rivers with a stable base flow and a silt or clay substrate, such as the River Loddon (above). *Potamogeton* spp. and *Myriophyllum spicatum* are prominent.



Coloured circles represent number of vegetation components – the highest numbers (the darkest circles) have the most diverse sites. Numbers in parentheses represent the number of sites in each category.

	Frequently abundant (Cover >5% in 50% or more of sites)	**Frequently present** (occurs in 50% or more of sites but not usually abundant)
Crowfoots	*Ranunculus penicillatus* ssp. *pseudofluitans**	*Ranunculus fluitans**
Starworts	–	*Callitriche platycarpa** *Callitriche stagnalis*$
Pondweeds	*Potamogeton pectinatus*$	*Potamogeton crispus*$ *Potamogeton lucens** *Potamogeton natans** *Potamogeton perfoliatus** *Zannichellia palustris*
Milfoils	–	*Myriophyllum spicatum*$
Bryophytes	–	*Fontinalis antipyretica** *Leptodictyum (Amblystegium) riparium*$ *Rhynchostegium riparioides*
Other aquatics	*Nuphar lutea* *Sagittaria sagittifolia*	*Butomus umbellatus* *Oenanthe fluviatilis*
Marginal species	*Rorippa nasturtium-aquaticum*	*Apium nodiflorum*
Guideline Number of Vegetation Components	6 or 7. In its unimpacted state, this is typically a diverse community type. However, many sites may have been adversely affected by eutrophication or habitat modification.	
Correspondence with EUNIS	C2.1B/P-24.44(p) – Eutrophic vegetation of spring brooks C2.34/P-24.44(p) – Eutrophic vegetation of slow-flowing rivers C2.28/P-24.44(p) – Eutrophic vegetation of fast-flowing streams Euhydrophyte communities of Palaearctic streams rich in nutrients, characterized in particular by *Ranunculus fluitans*, *Ranunculus circinatus*, *Zannichellia palustris* f. *fluviatilis*, *Potamogeton nodosus*, *Potamogeton lucens*, *Potamogeton pectinatus*, *Potamogeton crispus*, *Sparganium emersum*, *Sagittaria sagittifolia*, *Callitriche obtusangula*, *Nuphar lutea* and the moss *Fontinalis antipyretica*. (Source: Devillers *et al.* 2001).	
Likely European distribution	Widespread in lowland areas. Some catchments in Europe may provide better reference sites for this type of vegetation – the relatively unimpacted sections of the Rhône described by Bornette *et al.* (1998, 2001) may be useful.	
Common invasive aliens	*Impatiens glandulifera* *Mimulus* spp. *Elodea* spp. *Azolla* spp.	
Likely associated riparian communities	Fen, reedswamp and lowland mire. Wet woodland Lowland water meadows	

Type CB1 communities are often dominated by species, such as *Sagittaria sagittifolia* (right).

Nigel Holmes

Nigel Holmes

The River Wensum in Norfolk (above) is a good example of a lowland river with CB1 communities.

CB2: Base-rich *Ranunculus penicillatus* ssp. *pseudofluitans-Callitriche obtusangula* rivers, including chalk streams

This vegetation type typically occurs on small, lowland rivers on chalk and oolitic limestone geology in southern and eastern England. Flows are stable and substrates dominated by sand, gravels and pebbles. CB2 rivers are recognised as of international conservation importance through the UK Biodiversity Action Plan (BAP), and good examples include the rivers Test, Itchen and Frome, and sections of the Hampshire Avon cSAC. The Kent Stour, River Hull in Yorkshire and River Rother in West Sussex may also contain this vegetation type.

Ranunculus penicillatus ssp. *pseudofluitans*, *Callitriche* spp. and *Fontinalis antipyretica* often dominate the plant community. Dense riparian communities including *Berula erecta*, *Oenanthe fluviatilis*, *Rorippa nasturtium-aquaticum* and sedges such as *Carex acutiformis* are frequent. *Hippuris vulgaris* and *Groenlandia densa* may also occur in good examples of this type. *Ranunculus peltatus* may be present in the upper reaches (winterbournes) of such rivers.

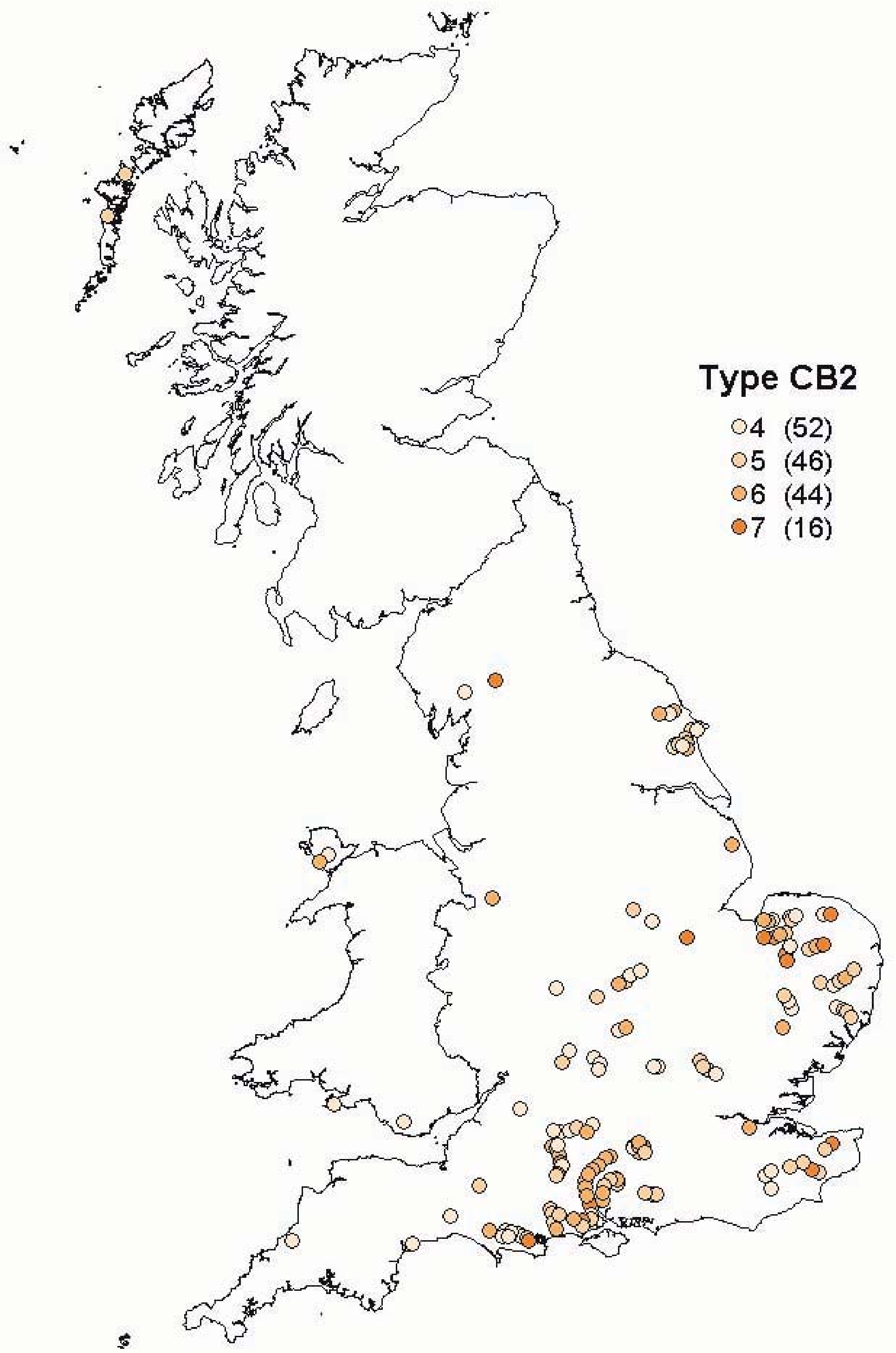
In marked contrast with CB1, species requiring slow flow or eutrophic conditions are generally absent. Thus *Potamogeton* spp., *Myriophyllum spicatum*, *Nuphar lutea* and *Sagittaria sagittifolia* are either rare or absent altogether (but see also the notes on effects of weed cutting, p. 54). The occurrence of *M. spicatum*, *S. sagittifolia* or *Potamogeton pectinatus*, or the dominance of *Zannichellia palustris*, may indicate eutrophication.

Due to its distribution in south-east England, CB2 is also particularly at risk from human impacts including river engineering, flow regulation, abstraction, and introduced species. This has led to chalk streams being the subject of a UK Biodiversity Action Plan (BAP).

Many examples of this type – even those of high conservation value – are unlikely to be entirely natural, since most small lowland streams tend to become heavily shaded by trees if not managed. The vegetation around chalk streams has developed through traditional management systems that have incidentally promoted high biodiversity, whilst engineering and abstraction have led to significant

Tristan Hatton-Ellis/CCW

CB2 communities are typically found in small, lowland rivers with stable flow and a substrate of sand, gravel or pebbles, such as the River Avon (above). These rivers often become shaded by trees if not managed.



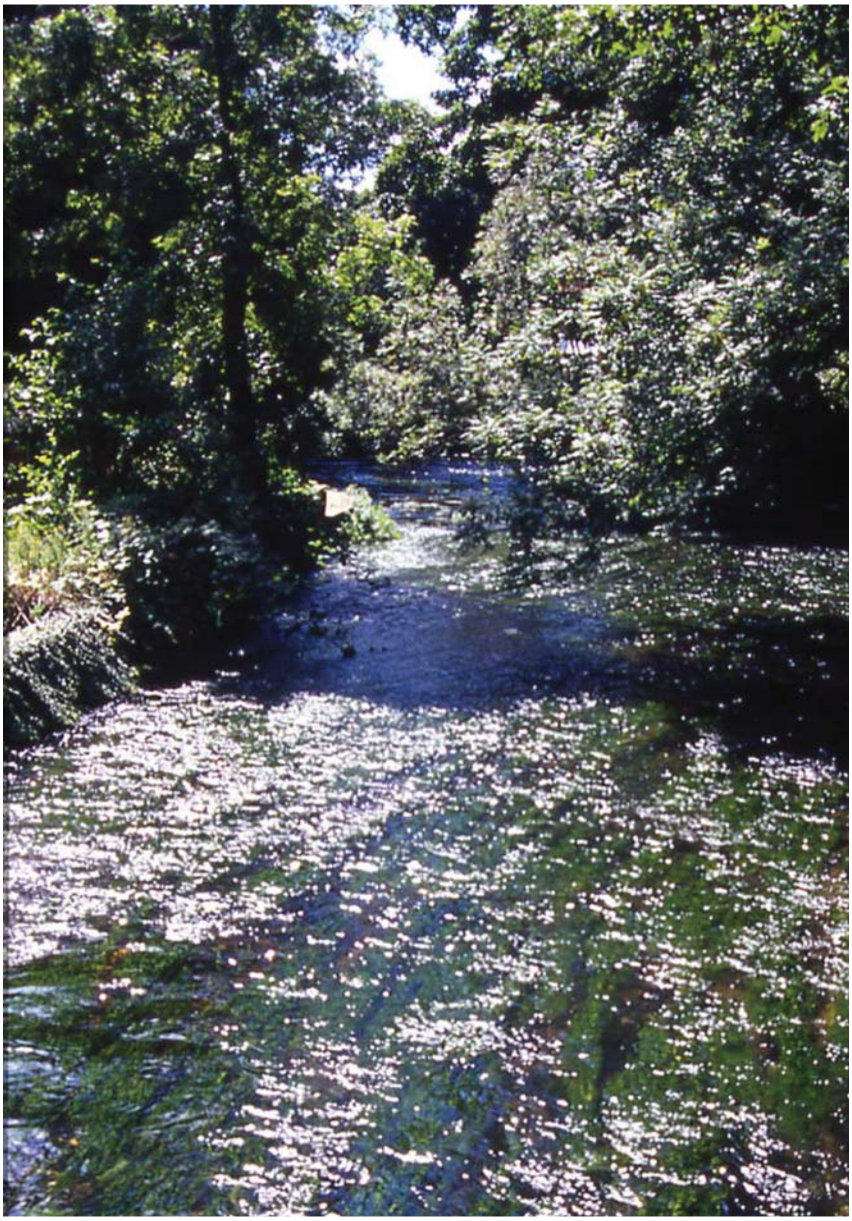
Coloured circles represent number of vegetation components – the highest numbers (the darkest circles) have the most diverse sites. Numbers in parentheses represent the number of sites in each category.

	Frequently dominant (Cover >5%)	**Frequently present**
Crowfoots	*Ranunculus penicillatus ssp. pseudofluitans**$	–
Starworts	*Callitriche obtusangula** *Callitriche platycarpa** *Callitriche stagnalis*$	–
Pondweeds	–	*Potamogeton crispus** *Potamogeton natans** *Zannichellia palustris*
Milfoils	–	–
Bryophytes	–	*Fontinalis antipyretica* *Leptodictyum (Amblystegium) riparium*$ *Rhynchostegium riparioides*
Other aquatics	*Berula erecta** *Oenanthe fluviatilis**	*Hippuris vulgaris*
Marginal species	*Rorippa nasturtium-aquaticum*	*Apium nodiflorum*
Guideline number of vegetation components	6. This variant does not usually contain *Myriophyllum*, hence only 6 of the 7 vegetation components are typically present. Sites with extensive *Myriophyllum spicatum* should be viewed as being potentially affected by eutrophication.	
Correspondence with EUNIS	C2.33/P-24.43(p) **–** Mesotrophic vegetation of slow-flowing rivers C2.27/P-24.43(p) **–** Mesotrophic vegetation of fast-flowing streams C2.1A/P-24.43(p) **–** Mesotrophic vegetation of spring brooks Euhydrophyte communities of Palaearctic streams moderately rich in nutrients, characterized in particular by *Berula erecta* (*Sium erectum*), *Mentha aquatica* f. *submersa*, *Potamogeton perfoliatus*, *Potamogeton natans*, *Groenlandia densa*, *Ranunculus peltatus*, *Ranunculus penicillatus*, *Ranunculus trichophyllus*, *Ranunculus fluitans*, *Ranunculus aquatilis*, *Callitriche truncata*, *Callitriche stagnalis*, *Nymphaea alba*, *Myriophyllum spicatum*. (Source: Devillers *et al*. 2001). Although a very distinctive habitat, correspondence with the generic EUNIS habitat for mesotrophic vegetation is only moderate. This is undoubtedly because, while chalk streams are more or less mesotrophic, the physical and chemical conditions in them are unusual. This makes them of considerable conservation value.	
Likely European distribution	Similar communities are likely to occur on base-rich geology, such as the chalk in Denmark and Belgium. According to Haslam (1987) some of the montane communities in the more base-rich alpine areas (e.g. Franken & Schwäben in Germany; northern Italy), and the Jurassic limestone streams of France, Britain and Germany are also referable to this general type.	
Common invasive aliens	*Mimulus* spp., *Elodea* spp., *Impatiens capensis*	
Likely associated riparian communities	Fen and lowland mire, wet woodland, lowland water meadows.	

reductions. Over-managed sections (especially where weed cutting is heavy) tend to result in a virtual monoculture of *Ranunculus* spp. This vegetation type coincides with Type III chalk, limestone and oolite rivers of Holmes *et al*. (1999a) and with the A17 *Ranunculus penicillatus* ssp. *pseudofluitans* community of Rodwell *et al*. (1995).

Type CB2 communities are often dominated by *Ranunculus penicillatus* ssp. *pseudofluitans* (right).

Nigel Holmes



David Withrington/English Nature

CB2 rivers such as the Itchen (left) are often recognized as important for conservation because of their habitats and macrophyte communities.

CB3: Large *Ranunculus fluitans* rivers

This vegetation type typically occurs on large rivers with a moderate-to-rapid current and somewhat variable flow regime. The underlying geology is usually sandstone or hard limestone, resulting in fairly base-rich, mesotrophic to eutrophic conditions. This type constitutes the classical 'non-chalk stream' *Ranunculus* river.

Ranunculus penicillatus ssp. *pseudofluitans* is often dominant, but perhaps the most characteristic species of this group is *Ranunculus fluitans*, which occurs with *Myriophyllum spicatum*, *Potamogeton* spp., *Rhynchostegium riparioides*, *Cinclidotus fontinaloides* and the ubiquitous *Fontinalis antipyretica*. *Callitriche* spp. are rare in this community.

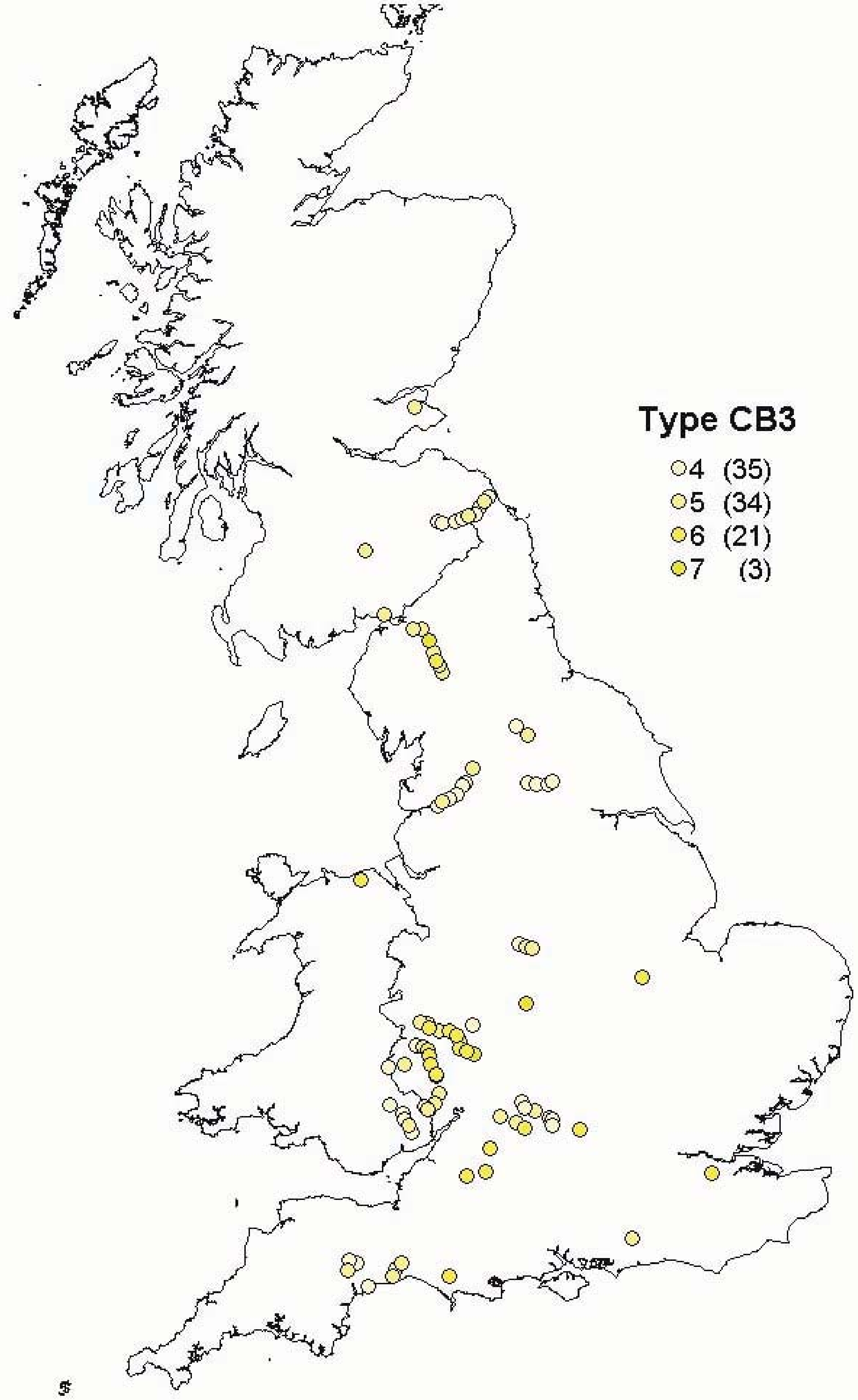
Rivers supporting this community often have heavily wooded banks, which can preclude the occurrence of an extensive riparian flora in places. However, they are often more than 20 m wide, usually allowing aquatic plants to grow without too much shading.

CB3 communities have a rather restricted distribution (in a band running south-west to north-east from east Wales and the Marches), but are often abundant in suitable catchments. The most important rivers supporting the community are the Wye, Teme, Ribble and Eden. The Tweed on the Scottish borders also contains a considerable quantity of this habitat. In many of these rivers several *Ranunculus* species are present, but frequently hybrids dominate.

The local nature of its distribution makes CB3 rather vulnerable to impacts at a catchment scale, especially those modifying the flow regime, such as reservoir construction. Diffuse pollution is also likely to be an issue, resulting in invasion by species such as *Potamogeton pectinatus* and *Elodea* spp.

Nigel Holmes

CB3 communities have a restricted distribution in wide rivers with wooded banks, such as the Wye (above).



Coloured circles represent number of vegetation components – the highest numbers (the darkest circles) have the most diverse sites. Numbers in parentheses represent the number of sites in each category.

	Frequently dominant (cover >5%)	**Frequently present**
Crowfoots	*Ranunculus fluitans** *Ranunculus penicillatus* ssp. *pseudofluitans*	–
Starworts	–	–
Pondweeds	*Potamogeton pectinatus*[$] *Potamogeton perfoliatus*	*Potamogeton crispus* *Zannichellia palustris*
Milfoils	*Myriophyllum spicatum*	–
Bryophytes	*Fontinalis antipyretica* *Rhynchostegium riparioides**	*Leptodictyum (Amblystegium) fluviatile* *Leptodictyum (Amblystegium) riparium*[$] *Cinclidotus fontinaloides* *Pellia endiviifolia*
Other aquatics	–	*Butomus umbellatus*
Marginal species	–	*Apium nodiflorum* *Rorippa nasturtium-aquaticum*
Guideline number of vegetation components	5–6. This community type is typically less diverse than others and 5 of the 7 vegetation components constitutes an acceptable threshold.	
Correspondence with EUNIS	C2.34/P-24.44(p) – Eutrophic vegetation of slow-flowing rivers. C2.28/P-24.44(p) – Eutrophic vegetation of fast-flowing streams. Euhydrophyte communities of Palaearctic streams rich in nutrients, characterized in particular by *Ranunculus fluitans*, *Ranunculus circinatus*, *Zannichellia palustris* f. *fluviatilis*, *Potamogeton nodosus*, *Potamogeton lucens*, *Potamogeton pectinatus*, *Potamogeton crispus*, *Sparganium emersum*, *Sagittaria sagittifolia*, *Callitriche obtusangula*, *Nuphar lutea* and the moss *Fontinalis antipyretica*. (Source: Devillers *et al*. 2001). The correspondence with the 'typical' EUNIS habitat is rather poor. Rivers of this type in Britain are perhaps steeper than is usual in Europe, and often associated with wooded banks. *Sagittaria sagittifolia* and *Ranunculus circinatus* in particular are not associated with this habitat.	
Likely European distribution	Not clearly described by Haslam (1987) but likely to be fairly common in the middle reaches of larger rivers (grayling and barbel zone) over sandstones and hard limestones.	
Common invasive aliens	*Elodea* spp., *Fallopia japonica*, *Heracleum mantegazzianum, Impatiens glandulifera*, *Mimulus* spp.	
Likely associated riparian communities	Broadleaved woodland	

Note: *Ranunculus fluitans* has been introduced to several rivers in northeast Britain and one in Northern Ireland, where it has subsequently become dominant and is now considered to be a problem species. Such rivers were excluded from the cluster analysis used to achieve the classification.

These two factors may interact in a complex manner. This vegetation type coincides mainly with Type VI sandstone and hard limestone rivers of Scotland and northern England of Holmes *et al*. (1999a) and with the A18 *Ranunculus fluitans* community of Rodwell *et al*. (1995).

Type CB3 communities are dominated by river water-crowfoot (*Ranunculus fluitans)* (right).

Nigel Holmes

Tristan Hatton-Ellis/CCW

***Potamogeton crispus* is often found in CB3 rivers, such as this stretch of the River Axe (above).**

CB4: Smaller meso-eutrophic rivers

This is the most widespread CB type in the UK, occurring in a variety of mesotrophic and eutrophic rivers and streams on various geologies from the southwest peninsula of England (River Tamar) to northern Scotland, with concentrations along the Welsh border and in southeast Scotland.

Most of the sites supporting this community are smaller, base-rich tributaries of large rivers. They are therefore particularly vulnerable to diffuse agricultural pollution or physical degradation resulting from land drainage, and it is likely that high-quality examples of this vegetation type were once more abundant.

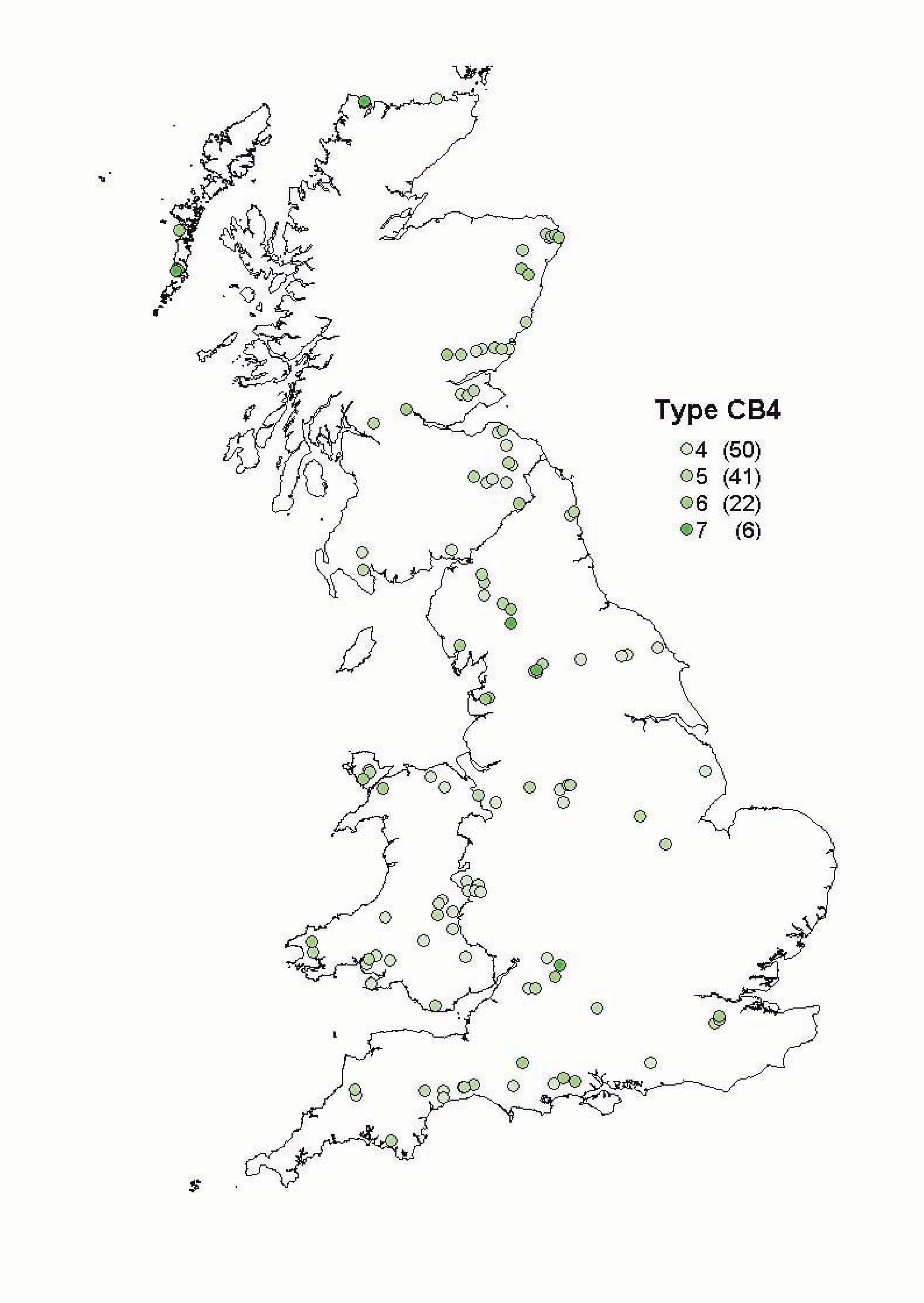
The community tends to occur in small tributaries of large catchments, such as the rivers Eden, Wye and Tweed, where suitable substrate (typically gravels and pebbles) and flow conditions occur and shading is not too dense. Plant species diversity at individual reaches is often not especially great, but there is considerable variation within the type, with some unusual combinations of plants.

Species typically associated with eutrophic conditions are generally excluded by fast flow or shading, but excessive growth of *Leptodictyum* (*Amblystegium) riparium*, *Apium nodiflorum*, *Potamogeton crispus* or algae may indicate eutrophication.

This community type does not have a close tie with any of the communities of Holmes *et al*. (1999a), although some match up with Type V, sandstone and hard limestone rivers of England and Wales. It does not match well with any of the communities of Rodwell *et al*. (1995).

Rob Cathcart/English Nature

Type CB4 communities tend to occur in small, base-rich tributaries of large catchments, such as the River Eden (above), with suitable gravel and pebble substrate.



Coloured circles represent number of vegetation components – the highest numbers (the darkest circles) have the most diverse sites. Numbers in parentheses represent the number of sites in each category.

	Frequently dominant	**Frequently present**
Crowfoots	*Ranunculus penicillatus* ssp. *pseudofluitans*	–
Starworts	–	*Callitriche hamulata** *Callitriche platycarpa** *Callitriche stagnalis*
Pondweeds	–	*Potamogeton crispus* *Potamogeton natans**
Milfoils	–	*Myriophyllum alterniflorum*
Bryophytes	*Fontinalis antipyretica* *Rhynchostegium riparioides*	*Leptodictyum (Amblystegium) fluviatile* *Leptodictyum (Amblystegium) riparium*$ *Pellia endiviifolia*
Other aquatics	–	–
Marginal species	–	*Apium nodiflorum* *Rorippa nasturtium-aquaticum*
Guideline number of vegetation components	4 or more. This community type is very variable in its nature, and attention should be paid to the geomorphology and physical characteristics of the site as well as its plant diversity.	
Correspondence with EUNIS	Correspondence with the generic EUNIS habitat for mesotrophic vegetation is rather poor. However, many of these sites are smaller streams with relatively low species diversity. Their conservation value may lie as much with their associated habitat such as mire, wet woodland or meadows rather than aquatic plant diversity *per se*. Additionally, such smaller streams may serve as important sources of material for recolonisation of impacted downstream sections.	
Likely European distribution	Widespread in lowland and semi-upland areas, in smaller streams not impacted by intensive agriculture.	
Common invasive aliens	*Fallopia japonica* *Heracleum mantegazzianum* *Impatiens glandulifera*	
Likely associated riparian communities	Lowland mire and fen Semi-improved grassland Broadleaved woodland	

Indian balsam (*Impatiens glandulifera*) is a common invasive species of rivers supporting CB4 communities.

Rob Cathcart/English Nature

Niall Grieve

The western River Cleddau (above) a CB4 river, has an unusually large community of *Sparganium emersum*.

CB5: Atlantic bryophyte *Callitriche hamulata/Ranunculus penicillatus ssp. penicillatus* rivers

This vegetation type tends to occur on base-poor, mesotrophic rivers with upland influences, usually over hard geology, resulting in flashy flow regimes. Substrate typically consists of gravels, pebbles and cobbles with scattered boulders.

Plant species diversity at individual reaches may be considerable as a result of the large number of bryophytes present. The growth of instream vegetation is frequently limited by shading, bed instability or current speed, but *Callitriche hamulata* will thrive in the faster flowing conditions, with *C. stagnalis* in backwaters and margins.

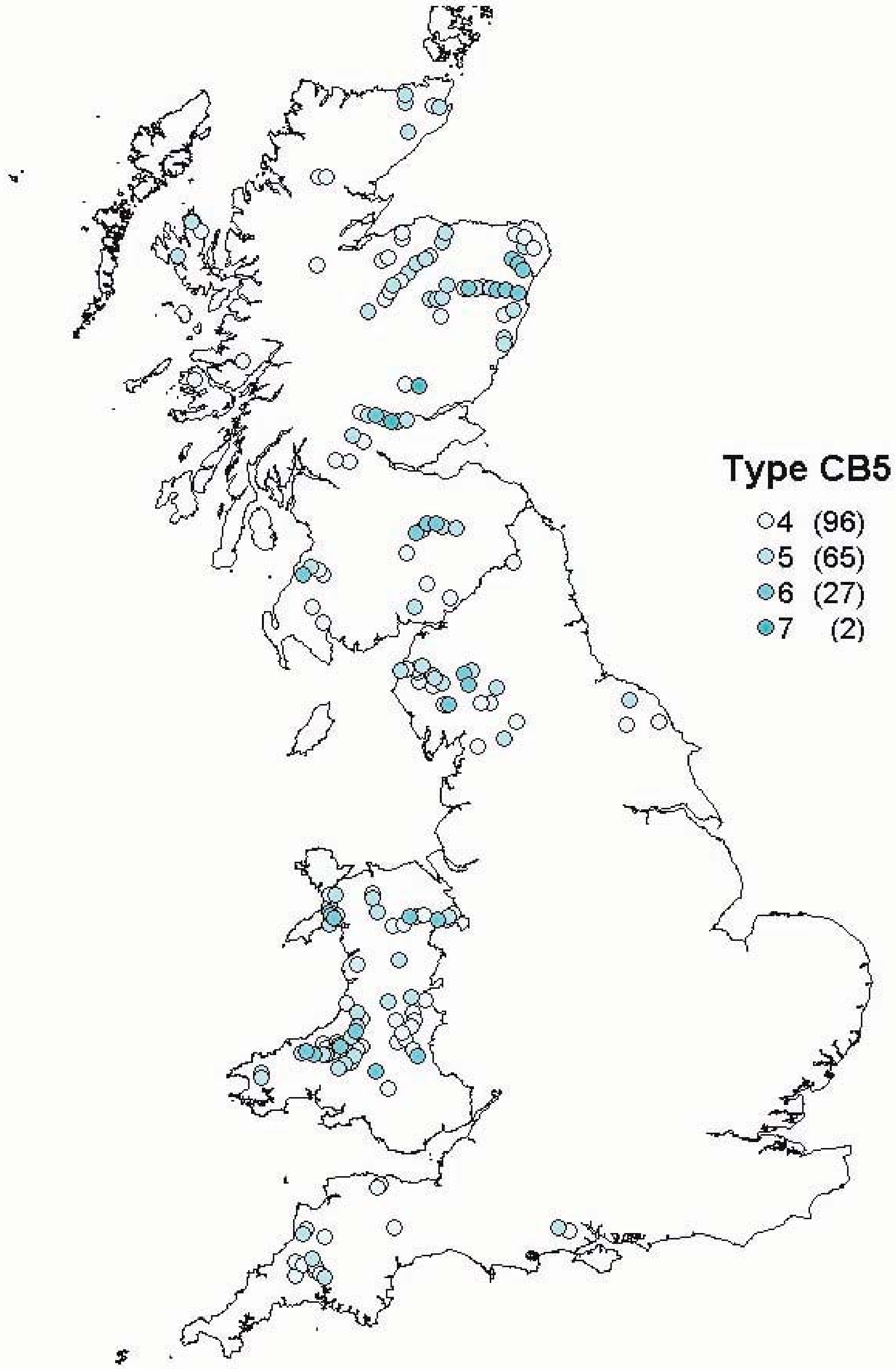
Ranunculus penicillatus ssp. *penicillatus* is restricted to southern and western Britain, where it is characteristic of CB5. Where the species occurs, it is normally very abundant and common. Growth form is very similar to *R. peltatus*, however, especially in small rivers, so definitive identification is difficult. Marginal plants are scarce in this habitat type, as sites that are not shaded are often grazed. However, *Rorippa nasturtium-aquaticum* may occur in the more base-rich, slow-flowing rivers.

This is a widespread CB type, occurring at a range of sites from the southwest peninsula of England (e.g. rivers Tamar and Torridge) to northern Scotland. However, the habitat is strongly linked to western Britain, and there are concentrations in Wales, the Lake District and eastern Scotland. Key sites include the Afon Teifi, Welsh Dee, Cumbrian Derwent, the Don and the Tweed.

Base-poor sites may be vulnerable to acidification, in which case an increase in *Juncus bulbosus* and *Scapania* spp. and loss of *Ranunculus* spp. and *Cinclidotus* (if present). The value of this habitat type in Scotland may have been undermined by the introduction of *Ranunculus* spp. from southern England. Based on its habitat preferences in Britain, this habitat type may well also occur in northwest France, especially Brittany.

Tristan Hatton-Ellis/CCW

Type CB5 communities are wide-ranging, but are particularly prevalent in base-rich, mesotrophic rivers in the western UK, such as the Dee in Wales (above).



Coloured circles represent number of vegetation components – the highest numbers (the darkest circles) have the most diverse sites. Numbers in parentheses represent the number of sites in each category.

	Frequently dominant	**Frequently present**
Crowfoots	–	*Ranunculus penicillatus* ssp. *penicillatus**
Starworts	*Callitriche hamulata** *Callitriche stagnalis*	–
Pondweeds	–	*Potamogeton crispus*
Milfoils	–	*Myriophyllum alterniflorum**
Bryophytes	*Fontinalis antipyretica* *Fontinalis squamosa** *Hygrohypnum luridum / ochraceum*	*Leptodictyum (Amblystegium) fluviatile* *Leptodictyum (Amblystegium) riparium*[$] *Brachythecium plumosum* *Chiloscyphus polyanthos* *Cinclidotus fontinaloides* *Jungermannia* spp. *Pellia epiphylla* *Pellia endiviifolia* *Racomitrium aciculare* *Rhynchostegium riparioides* *Scapania spp.* *Schistidium alpicola* *Thamnobryum alopercurus*
Other aquatics	–	*Juncus bulbosus*[$]
Marginal plants	–	*Rorippa nasturtium-aquaticum*
Guideline number of vegetation components	5 or more. These sites may have a wide range of bryophytes but the occurrence of higher plants tends to be rather patchy. Good-quality sites typically have a high bryophyte diversity (10 or more species) and four or more other macrophyte components, including healthy beds of *Ranunculus penicillatus* ssp. *penicillatus* and *Callitriche hamulata*.	
Correspondence with EUNIS	C2.33/P-24.43(p) – Mesotrophic vegetation of slow-flowing rivers. C2.27/P-24.43(p) – Mesotrophic vegetation of fast-flowing streams. C2.1A/P-24.43(p) – Mesotrophic vegetation of spring brooks. Euhydrophyte communities of Palaearctic streams moderately rich in nutrients, characterized in particular by *Berula erecta* (*Sium erectum*), *Mentha aquatica* f. *submersa*, *Potamogeton perfoliatus*, *Potamogeton natans*, *Groenlandia densa*, *Ranunculus peltatus*, *Ranunculus penicillatus*, *Ranunculus trichophyllus*, *Ranunculus fluitans*, *Ranunculus aquatilis*, *Callitriche truncata*, *Callitriche stagnalis*, *Nymphaea alba*, *Myriophyllum spicatum*. C2.18/P-24.41(p) - Acid oligotrophic vegetation of spring brooks C2.25/P-24.41(p) - Acid oligotrophic vegetation of fast-flowing streams Euhydrophyte communities of Palaearctic streams poor in nutrients and in lime, with, in particular, *Myriophyllum alterniflorum*, *Potamogeton polygonifolius*, *Callitriche hamulata*, *Littorella uniflora*, *Juncus bulbosus*, *Scirpus fluitans* or acidophilous mosses and algae. In Iceland, *Montia fontana*, *Potamogeton filiformis*, *Ranunculus trichophyllus* (*Ranunculus confervoides*, *Ranunculus aquatilis* var *diffusus*) and *Fontinalis antipyretica* characterize the community in clear, slowly flowing waters. (Source: Devillers *et al*. 2001) The correspondence with EUNIS is particularly poor here, most likely due to the restricted geographical distribution of this type and its distinctive physical character. The vegetation is distinctly mesotrophic but also base-poor and fast-flowing, resulting in the absence of most of the species characteristic of the mesotrophic type listed above. However, *Ranunculus penicillatus* ssp. *penicillatus, Callitriche hamulata* and *Fontinalis* spp. may proliferate, while *Juncus bulbosus* and *Potamogeton polygonifolius* are generally absent.	
Likely European distribution	Not known, but perhaps restricted. This habitat requires Atlantic conditions over resistant rocks. Likely to occur in Brittany, Ireland and Northern Iberia. More species-poor variants may occur in continental Europe.	
Common invasive aliens	*Fallopia japonica, Impatiens glandulifera*	
Likely associated riparian communities	Broadleaved woodland, semi-improved grassland	

Pete Scarlett/CEH

Callitriche hamulata **is characteristic of CB5 communities, as in the upper River Gwyrfai, Wales (above).**

Tristan Hatton-Ellis/CCW

The River Wye at Newbridge is a key site for CB5 communities, which are found mainly in western Britain.

CB6a: Slow-flowing base-poor rivers

This is an uncommon vegetation type because of the rarity of its relatively specific habitat requirements. CB6a tends to occur in relatively isolated reaches on base-poor rivers with a low gradient. This allows species more typical of standing waters, such as *Nuphar lutea*, *Littorella uniflora* and *Menyanthes trifoliata*, to occur. Such sites often occur in raised bogs, such as Cors Caron in Wales, and this combination of lack of shade and peaty substrate means that aquatic bryophytes other than *Sphagnum* spp. are uncommon. Associated species include *Equisetum fluviatile*.

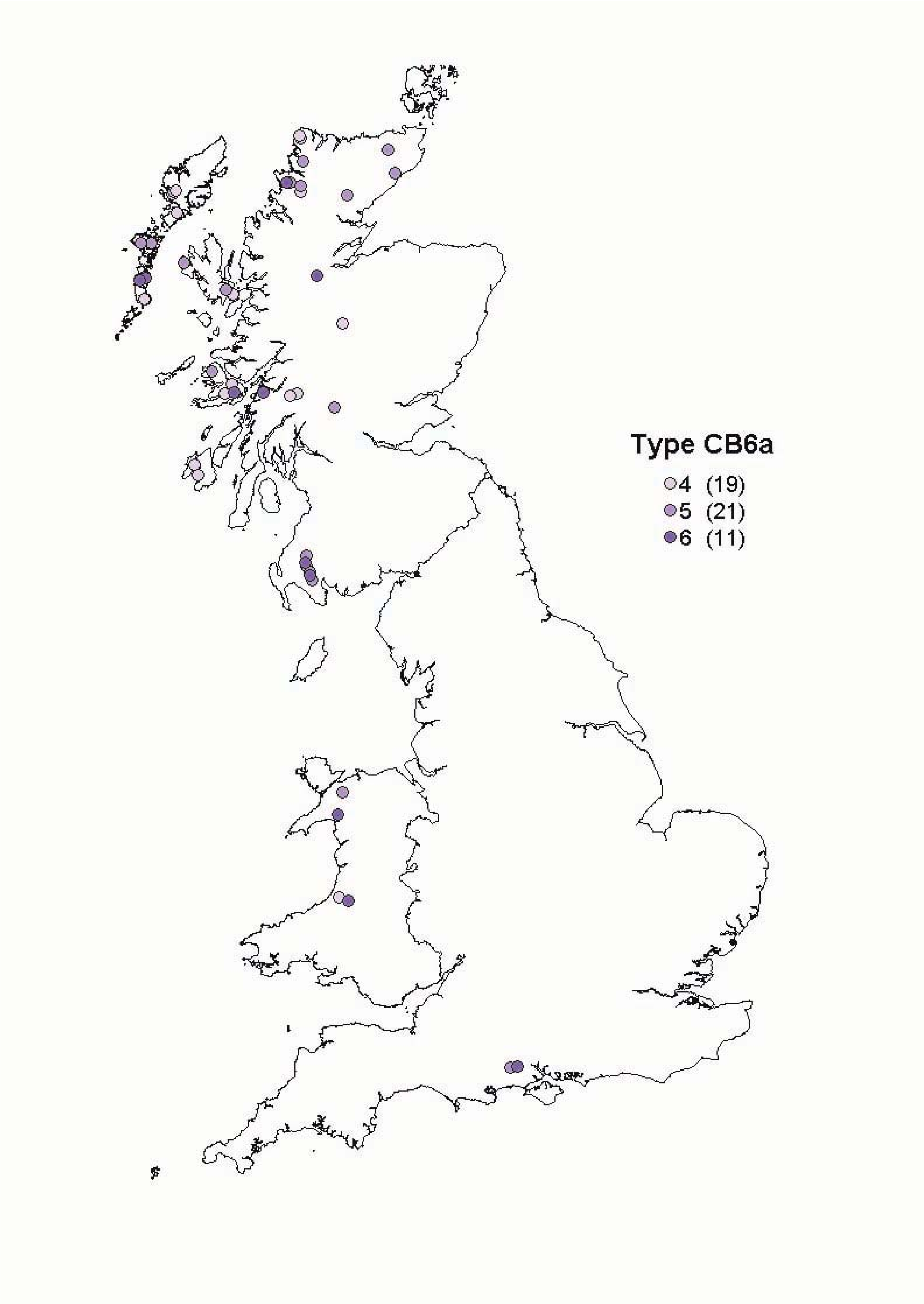
CB6a corresponds broadly to the lake type 'H3130 Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*', and it is likely that many sites are former lakes or immediately downstream of lake outflows. The Bladnoch in Scotland is a particularly important example. Some of the more base-poor sites may be vulnerable to acidification.

Sphagnum pulchrum (right) is characteristic of raised bogs such as Cors Caron (below), fed by rivers supporting CB6a communities.

Alan Hale

Tristan Hatton-Ellis/CCW

Type CB6a communities are rare because their preferred habitat is scarce. Raised bogs, such as Cors Caron in Wales (above), support standing-water species such as yellow water-lily (_Nuphar lutea_).



Coloured circles represent number of vegetation components – the highest numbers (the darkest circles) have the most diverse sites. Numbers in parentheses represent the number of sites in each category.

	Frequently dominant	**Frequently present**
Crowfoots	–	–
Starworts	–	*Callitriche hamulata* *Callitriche stagnalis*
Pondweeds	*Potamogeton polygonifolius*	*Potamogeton natans**
Milfoils	*Myriophyllum alterniflorum*	–
Bryophytes	–	*Blindia acuta* *Fontinalis antipyretica* *Sphagnum* spp.
Other aquatics	*Littorella uniflora** *Juncus bulbosus*	*Nuphar lutea**
Marginal plants	-	*Menyanthes trifoliata**
Guideline number of vegetation components	4 or more. These sites may have a wide range of bryophytes but occurrence of higher plants tends to be rather patchy.	
Correspondence with EUNIS	C2.18/P-24.41(p) – Acid oligotrophic vegetation of spring brooks. C2.25/P-24.41(p) – Acid oligotrophic vegetation of fast-flowing streams. Euhydrophyte communities of Palaearctic streams poor in nutrients and in lime, with, in particular, *Myriophyllum alterniflorum*, *Potamogeton polygonifolius*, *Callitriche hamulata*, *Littorella uniflora*, *Juncus bulbosus*, *Eleogiton (Scirpus) fluitans* or acidophilous mosses and algae. In Iceland, *Montia fontana*, *Potamogeton filiformis*, *Ranunculus trichophyllus* (*Ranunculus confervoides*, *Ranunculus aquatilis* var *diffusus*) and *Fontinalis antipyretica* characterize the community in clear, slowly flowing waters. (Source: Devillers *et al*. 2001). This vegetation type generally concurs well with the EUNIS classification, though it generally occurs in rather slow-flowing water and not in spring brooks or fast-flowing streams.	
Likely European distribution	Probably widespread but local over acidic substrates, usually in association with glacial landforms, especially lakes. Possibly also over oligotrophic, acidic sands.	
Common invasive aliens	None	
Likely associated riparian communities	Bog and fen Wet heath Semi-upland scrub Wet woodland Acid grassland	

The acidic standing waters of CB6a habitat are ideal for species such as *Litorella uniflora*, *Potamogeton polygonifolius* and *Oenanthe crocata* (right).

Tristan Hatton-Ellis/CCW

Tristan Hatton-Ellis/CCW

The River Gwyrfai in North Wales is an example of a river that supports CB6a communitites.

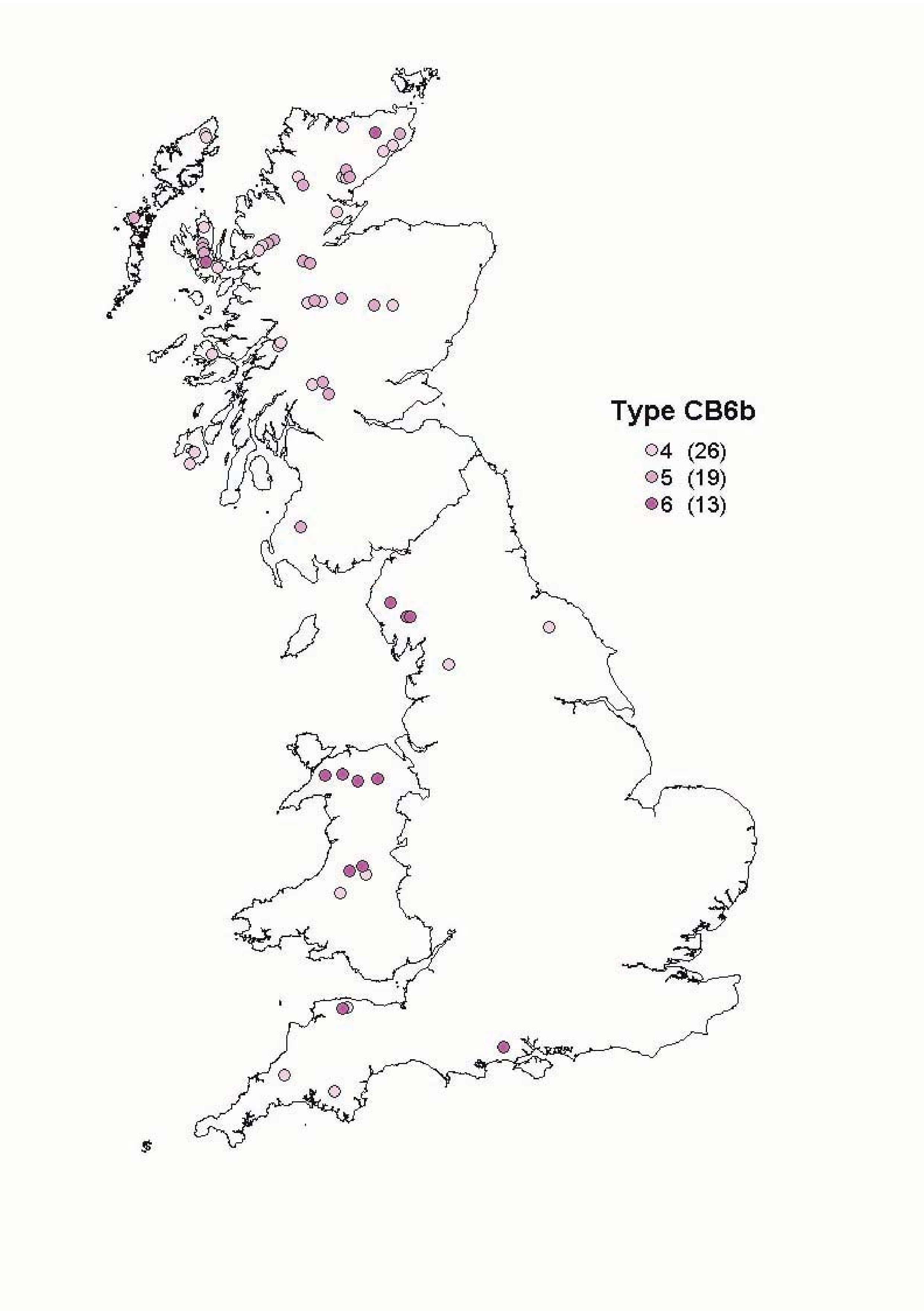
CB6b: Fast-flowing, bryophyte-dominated rivers

Widespread in the base-poor, hard rock areas of England, Scotland and Wales, but rarely extensive. This habitat type is mainly restricted by physical conditions to upland sections of river that are fast flowing but stable-bedded, permitting the establishment of an association of many bryophytes with more than one of the following taxa: *Myriophyllum alterniflorum*, *Fontinalis antipyretica*, *Juncus bulbosus*, *Potamogeton polygonifolius* or *Callitriche hamulata*.

The extent of this habitat may have been reduced by reservoir construction, overgrazing of upland areas and acidification. However, the high energy of most of the rivers in which it occurs mean it is less vulnerable to the impacts that affect other CB types, such as siltation and eutrophication.

Tristan Hatton-Ellis/CCW

CB6b rivers are often dominated by mosses, such as the River Artro in Wales (above). This community is restricted to upland, high-energy waters, and is less vulnerable to eutrophication than other CB types.



Coloured circles represent number of vegetation components – the highest numbers (the darkest circles) have the most diverse sites. Numbers in parentheses represent the number of sites in each category.

	Frequently dominant	**Frequently present**
Crowfoots	–	–
Starworts	–	*Callitriche hamulata** *Callitriche stagnalis*
Pondweeds	–	*Potamogeton polygonifolius**
Milfoils	*Myriophyllum alterniflorum**	–
Bryophytes	*Fontinalis antipyretica* *Scapania undulata*	*Blindia acuta* *Brachythecium plumosum* *Chiloscyphus polyanthos* *Dichodontium pellucidum* *Fontinalis squamosa* *Hygrohypnum luridum/ochraceum* *Hyocomium armoricum* *Jungermannia* spp. *Marsupella* spp. *Nardia* spp. *Pellia epiphylla* *Racomitrium aciculare* *Rhynchostegium riparioides* *Schistidium alpicola* *Sphagnum* spp.
Other aquatics	*Juncus bulbosus**	-
Marginal plants	-	-
Guideline number of vegetation components:	At least four should be present. This vegetation type is naturally species-poor, although as with other CB communities on hard substrates a reasonable diversity of bryophytes may occur.	
Correspondence with EUNIS	C2.18/P-24.41(p) – Acid oligotrophic vegetation of spring brooks. C2.25/P-24.41(p) – Acid oligotrophic vegetation of fast-flowing streams. Euhydrophyte communities of Palaearctic streams poor in nutrients and in lime, with, in particular, *Myriophyllum alterniflorum*, *Potamogeton polygonifolius*, *Callitriche hamulata*, *Littorella uniflora*, *Juncus bulbosus*, *Scirpus fluitans* or acidophilous mosses and algae. In Iceland, *Montia fontana*, *Potamogeton filiformis*, *Ranunculus trichophyllus* (*Ranunculus confervoides*, *Ranunculus aquatilis* var *diffusus*) and *Fontinalis antipyretica* characterise the community in clear, slowly flowing waters. (Source: Devillers *et al*. 2001) This vegetation type generally concurs well with the EUNIS classification, though faster flows generally prevent the establishment of *Littorella*.	
Likely European distribution	Presumably widespread in more or less acidic, submontane areas.	
Common invasive aliens	*Fallopia japonica* *Impatiens glandulifera* *Rhododendron ponticum*	
Likely associated riparian communities	Broadleaved woodland Wet heath Valley mire Acid grassland	

Potamogeton polygonifolius **(right) is characteristic of CB6b vegetation communities.**

Tristan Hatton-Ellis/CCW

Tristan Hatton-Ellis/CCW

This stretch of the River Lledr in Wales supports CB6b vegetation communities in summer, but is regularly exposed to floods in the winter. The above photo was taken in November.

Overview of CB communities in Britain.

From the descriptions above, it is apparent that *Ranunculion fluitantis* and *Callitricho-Batrachion* communities occur in a very wide range of river types, including all river types previously described by Holmes *et al*. (1999a) in the UK. However, *Callitricho-Batrachion* vegetation differs greatly in its prevalence among these river types. Furthermore, a range of groupings can be identified along an ecological scale, relating primarily to differences in substrate, gradient, base status and trophic status.

The intention of this classification is to assist in management, rather than to provide a detailed phytosociological description of every possible variation. Since different river types are prone to, and respond differently to, different threats, it is important to subdivide the community. Although this can to some extent be carried out arbitrarily using physical variables, this approach includes the biological response to these.

Although an attempt was made to remove the most impacted sites, it is nevertheless likely that human impacts have played a significant part in shaping the classification. There are very few river systems in Britain that are not subject to significant human impact, and most of these are in northern and western Britain, in rivers that are often less important for *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation.

Declines in the diversity and quality of aquatic habitats over the last century are well documented (e.g. Wiegleb *et al*. 1991; Harper 1992; Preston & Croft 1997; Demars & Harper 2003). Nevertheless, there are still a number of important rivers for aquatic macrophytes, even in intensively farmed areas such as southeast England. Furthermore, the inclusion of some data surveyed in the late 1970s and early 1980s allows the analysis of past as well as present communities.

Key factors affecting CB communities

The basic requirements of all plants can be summarised as space, light, substrate, minerals, nutrients and water. The key factors affecting aquatic macrophytes (geology, water chemistry and land use; climate and flow regime; geomorphology; and anthropogenic factors such as disturbance, shading and management) are highly interlinked, acting in combination and over varying time scales. It is therefore often difficult to obtain a clear understanding of the relative importance of each. The effects of geology and flow are of primary importance, and this generally determines which plants can occupy specific locations in the channel (Butcher 1933, Haslam 1978). Flow velocity is thought to be the single most important control on the condition of *Ranunculus* (Environment Agency 2001a).

General attributes of healthy river habitat

Although there are significant differences among the different communities, there are nonetheless various factors common to all river reaches supporting healthy aquatic plant communities. These can be best considered as habitat structure, comprising the physical environment of the river, and the biological species, comprising the plant community and associated species.

Bankside habitat should normally consist of stable banks with a dense growth of riparian vegetation, consisting of any naturally occurring plant community. This will usually be a wetland, wet grassland, mire, tall herb or wet woodland community, though heath and scrub may also sometimes occur. However, semi-natural habitats such as these will have often been replaced by improved grassland or arable fields. Under these conditions, it is important to have a riparian habitat capable of reducing sediment and nutrient inputs. Further discussion of these issues can be seen below.

Management of shade is critical to determining the structure of aquatic plant communities. Appropriate levels of shading vary greatly both within and among CB communities (see the community descriptions and the discussion below). On larger rivers 20 m or more wide, the management of shade is relatively unimportant because even large trees will not be able to exclude the growth of aquatic macrophytes. Marginal communities, however, may be significantly affected. Along smaller streams, especially those <5m in width, a 'tunnel vegetation' may develop, usually excluding CB communities. In some instances, tree coppicing may be considered desirable to encourage luxuriant CB vegetation in headwaters. However, such activities should generally be avoided. In these smaller streams CB communities are not necessarily the natural vegetation, and it is usually more appropriate to conserve these reaches with the needs of other conservation features such as otters, fish, bryophytes and invertebrates in mind. Additionally, removal of tree cover in upstream areas may significantly harm aquatic communities downstream by increasing silt and nutrient inputs.

There is a limited amount of scientific literature relevant to determining the ecological requirements of macrophyte assemblages in both the UK and Europe. Most R&D has focused on the needs of individual species (e.g. Westlake 1982; Westlake & Dawson 1986, 1988; Casey & Downing 1976; Dawson 1976, 1978, 1979, 1980, 1981, 1989; Haslam 1978; Ham *et al*. 1982a). Recent research on *Ranunculus* species in southern chalk streams (Environment Agency 2001a) has revealed how little is known about the requirements of a single genus of plants. There remain many gaps in understanding of the reproductive biology of individual species, the identification and distribution of subspecies, and the ecological tolerances of plant assemblages.

Geology

At the catchment scale, geology has a fundamental influence on river type and ecology, affecting topography, patterns of drainage and flow, substrate type, water chemistry, and land use (Haslam 1987). Soil type, which is related to geology, has been suggested as the most important factor in predicting the

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Geology has a major influence on river habitats, from water and soil pH to topography and flow, and, consequently, ecology. The River Eden (above) runs over limestone and has CB3, 4 and 5 communities.

character of plant communities in rivers (Holmes *et al*. 1998). Geology is the primary control on bed slope (and hence stream power), determines the initial pH of water draining the catchment, and thus has a major influence on plant composition.

Riis *et al*. (2000), working on Danish streams, recognised several communities in relation to alkalinity that bear a broad resemblance to UK communities, in spite of the narrower environmental range of streams in Denmark. Stream size was also noted as a major factor. Rivers in the UK cover a more diverse range of conditions from highland (torrential) oligotrophic habitats through to lowland (more stable) eutrophic habitats. The classification produced by Holmes *et al*. (1999a) highlights geology, altitude and gradient as important features separating the four main river groups.

Rivers that flow over mixed or changing geology will generally have more diverse plant communities than those flowing over more uniform conditions. Rivers are particularly dynamic habitats: channel morphology adapts to the supply of water and sediment from upstream, while disturbances such as floods and erosion alter the character of the habitats present and reset the process of succession, resulting in a mosaic of habitats and communities. Plants will colonise areas with suitable conditions and may then modify the local environment by their presence. This is particularly true of *Ranunculus* species in low-energy chalk streams, which have less physical diversity than other river types due to the more stable flow regime.

A recent study (Environment Agency 2001a) lists the following combination of factors (measurable variables) and drivers (natural and artificial influences on factors) thought to be the most important controls governing the extent and condition of *Ranunculus* in chalk rivers:

- Factors: flow (volume, velocity and depth); substrate and siltation; water quality (and suspended solids); light and temperature; physical channel characteristics; competition and colonisation; grazing.
- Drivers: natural climate cycles; abstraction and catchment water use; point-source enrichment and diffuse pollution; channel and vegetation management; shading by algae; river rehabilitation schemes.

Velocity and flow regime were highlighted as prime factors governing the extent and condition of

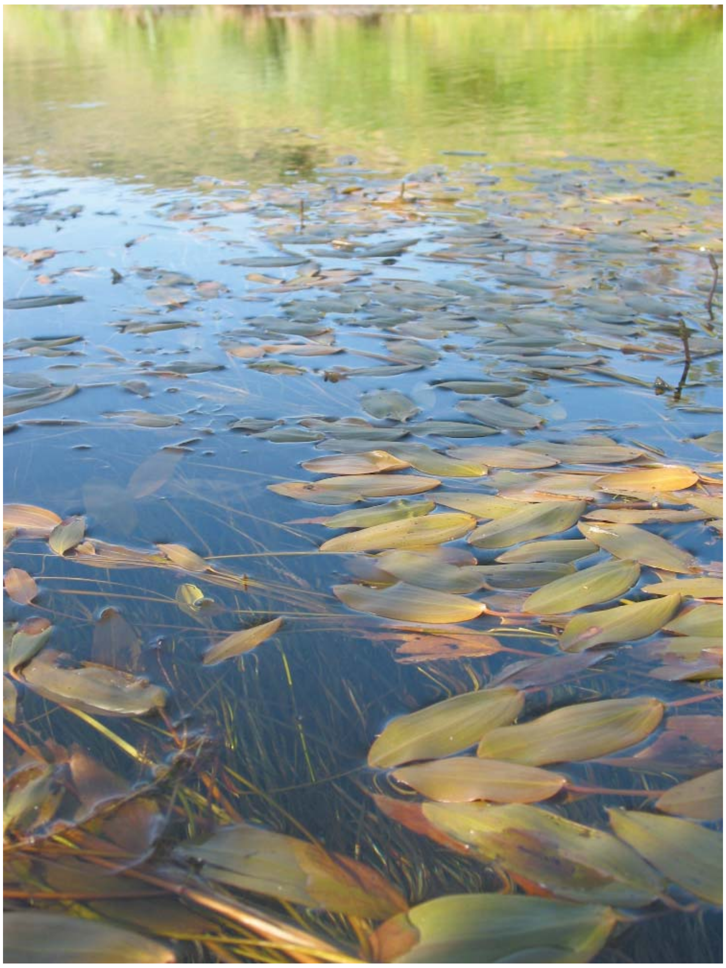
Tristan Hatton-Ellis/CCW

Rivers with an unstable substrate, such as this stretch of the Twyi at Llanwrda, are unsuitable for CB vegetation communities.

Ranunculus, with climate the strongest influencing driver. The research also highlighted that seasonal fluctuations are more important than absolute values. Other key drivers that change flow velocity include abstraction, channel and vegetation management, and physical dimensions of the channel.

Flow regime

Stream power directly affects river geomorphology and physical habitat. High-flow events are particularly important in determining the composition of physical features in the channel, leading to erosion, transportation of sediments and bedload (RSPB *et al*. 1994). The dynamic nature of rivers means that they are constantly adjusting to changes in flow regime and sediment load, and this leads to changes in fluvial processes and associated habitats. Due to regular disturbance, river macrophytes rarely reach a climax condition but frequently occur as transient communities, and are strongly influenced by prevailing weather conditions.



Tristan Hatton-Ellis/CCW

Macrophytes such as broadleaved pondweed (*Potamogeton natans*) can cope with a wide range of flow conditions.

Individual species are adapted to specific flow types in several ways – for example, anchoring strength, resistance to battering, tangling, and abrasion (Haslam 1978; Willby *et al*. 2000, 2001). Some species, such as *Potamogeton natans* and *Ranunculus aquatilis*, can cope with a wide range of flow conditions. The presence of macrophytes in a channel will also create different flow conditions and sediment relationships – for example, still zones within beds, secondary upwelling and accelerated flow around plants (Padmore 1998, Harper *et al*. 1999). Dawson & Charlton (1988) have produced a bibliography of work relating to the hydraulic resistance of individual macrophyte species.

Water quantity and the timing of changes in supply have a primary influence on aquatic plant communities (Haslam 1978). The growth pattern of *Ranunculus penicillatus* subsp. *pseudofluitans* has been demonstrated to coincide with maximum flow in chalk streams (Dawson 1976). Holmes (1996) has described how winterbourne communities react to changes in duration of flow. The season and extent of inundation is critical to the development and stability of plant communities in these systems, which exhibit considerable temporal and spatial variation in relation to water supply.

Haslam (1987) observed that hill stream communities had increased cover of *Elodea canadensis* and *Ranunculus* in years of low rainfall, due to reduced erosion of the substrate and less physical battering of plants. However, *Ranunculus fluitans*, which requires swift water for good growth, declined notably due to low rainfall during the mid-1970s. Conversely, excessive spates in upland and hill streams will lead to the loss of channel macrophytes due to washout. If the UK is to experience more extreme climate events, including more frequent severe flood events, macrophyte communities are likely to change in many rivers that are prone to spates, or are affected by river regulation, land-use change and increasing run-off.

A number of species share a wide tolerance to abiotic gradients. Some taxa are clearly associated with specific microhabitats, for example, mosses are frequently the only plants found in fast currents (0.6 m s^{-1}) over rock substrate (French & Chambers 1996). A natural (relatively unmodified) flow regime is required for both plant communities and channel geomorphology to be in favourable condition, exhibiting typical dynamics for the river type. Increased flow and turbulence improves the exchange of gases and nutrients, reduces the growth of epiphytes and increases photosynthesis. Water quantity has a major influence on water quality through effluent dilution, oxygenation levels and sediment removal capacity. The effects seem to be greatest at times of low flow, when problems due to excess sediment or nutrients will be exacerbated.

Alterations to flow regime can change the composition of substrate in response to different hydraulic forces and energy. A clean substrate is an important part of the river habitat associated with CB communities. This is supported by observations on the occurrence of *Ranunculus penicillatus* in rivers in Northern Ireland (ATEC 2001), with swift to moderate currents over gravel-pebble substrate.

Water quality and trophic status

Water quality (particularly phosphorus and nitrates) strongly influences the species composition, extent and condition of riverine plant communities. The key parameters include alkalinity, pH, nitrate, phosphate, potassium and suspended solids. Eutrophication is regarded as the major water quality issue currently affecting plant communities in British rivers (Environment Agency 2000).

Trophic status and eutrophication

Eutrophication is often defined as 'the biological effects of an increase in concentration of plant nutrients' (Harper 1992). Habitats with low primary production are usually described as oligotrophic, and those with high primary production as eutrophic. In most habitats, trophic status is predicted by nutrient concentration, because there are few limiting factors. However, in rivers, trophic status is not a simple function of nutrient status, because plant growth is also strongly affected by various other factors, most notably flow, shading and base status (Schneider & Melzer 2003). This does not mean that nutrient concentration has no effect on plant community – quite the reverse – but it does make setting targets difficult. Furthermore, the measurement of trophic status in rivers is more difficult than in standing waters, because environmental conditions are much more variable.

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Channel modification, such as as canalisation, reduces river heterogeneity and habitat diversity, resulting in a lack of biodiversity. Part of the River Teifi, Wales (above), was canalised in the 1940s, but work is underway to reintroduce bends and improve the habitat.

Table 4. Suggested soluble reactive phosphorus values for different river types in Britain (adapted from Mainstone, Parr & Day 2000; Environment Agency 2000).

		(mg l^{-1})
Upland watercourses	CB6a, CB6b	0.002
Winterbournes	CB2, CB4	0.04
Mid-altitude watercourses on hard substrates.	CB5, CB4	0.06
Lowland small and medium watercourses on chalk and sandstone	CB2, CB4	0.06
Lowland large rivers on chalk and sandstone	CB3	0.1
Lowland alluvial and clay rivers	CB1	0.2

In lakes, aquatic plants are sensitive to eutrophication because they are shaded by planktonic algae. These conditions are unlikely in all but the slowest flowing rivers (CB1), but a far greater cause for concern is overgrowth by epipelic filamentous algae that compete directly with vascular plants for light and nutrients. Increased loading of organic matter and sediment is also frequently associated with eutrophication problems.

The Mean Trophic Rank (MTR) methodology has been developed to monitor watercourses in respect of the Urban Waste Water Treatment Directive (UWWTD), and provides Species Trophic Rank (STR) scores for the main macrophyte species (Holmes *et al.* 1999b). In mesotrophic waters an increase in nutrients usually leads to faster plant growth and increased biomass. In Europe, where *Ranunculus fluitans* has a wider range than in the UK, the species is considered relatively tolerant of eutrophication (Eichenberger & Weilenmann 1982). This view is probably correct as long as adequate flow is maintained. However, *R. fluitans* is likely to be much more sensitive to low flows under eutrophic conditions. Spink *et al.* (1997) provide evidence for a water chemistry and sediment nutrient relationship to explain the distribution of *Ranunculus* species in British rivers – the key variables being water pH; sediment calcium, nitrogen and potassium concentrations; management and land use.

In England and Wales, water quality is linked to habitat quality and river type through the use of River Ecosystem (RE) classes. These are measures that relate to water quality parameters in the context of river type and associated ecosystem use and function. For chalk rivers a special ecosystem target for phosphate has been set (Mainstone *et al.* 2000), and for soluble reactive phosphorus (SRP) the following criteria have been proposed (Table 4).

Channels with a naturally functioning floodplain are better able to maintain habitat and water quality. The riparian strip and marginal vegetation can provide an effective buffer, intercepting sediments and nutrients. Channel macrophytes also help maintain overall water quality, and act as in-stream filters and purifiers. They trap sediment, increase channel habitat diversity, act as a substrate for a diverse microbiological community and directly take up nutrients and other pollutants, whilst marginal plants reduce erosion and help provide bank stability (Haslam 1978, RSPB *et al.* 1994).

Physical habitat

Rivers are linear features with overall transport (of water, sediment and biota) from source to mouth, and thus represent continua. The conditions at any particular location will not only depend upon its immediate structure and management, but also on processes upstream and across the catchment. For example, changing land use and increasing land drainage will alter the natural flow regime downstream, with more severe and extreme flow conditions (spates), leading to increased erosion, sediment transport and wash out of macrophytes. Thus the quality of headwaters can alter the condition of the whole watercourse (Vannote *et al.*1980).

The linear nature of watercourses has been identified as having specific relevance as a wildlife corridor, including links with floodplain habitats. Article 10 of the Habitats Directive specifies that rivers and hedgerows should be recognised for their value in the wider landscape, particularly in relation to the migration, dispersal and genetic exchange of species. Bankside structure and condition are therefore important components of watercourses.

Habitat quality

There are very few remaining examples of rivers with entirely natural habitat in the UK (Raven *et al.* 1998). Channel modification reduces heterogeneity and habitat diversity with a subsequent impoverishment of the biota (Harper *et al.* 1999). Using the River Habitat Survey (RHS) database, reference conditions (unmodified sites) can be used to evaluate the key physical characteristics and representativeness of a site in relation to river type. An objective assessment can then be made of the impacts of past modifications and current management. Harper *et al.* (1999) compared functional habitat distribution in natural and modified rivers, and quantified habitat expectancy (predicted and observed), depth-flow relationships, and natural channel width. The two main impact types were over-deepening (impoundment) and over-widening. This type of approach has useful applications in directing remedial measures to improve river habitat by identifying which functional habitats are missing.

Willby *et al.* (2001) found that there was no consistent match between aquatic plant groups and habitat utilisation, and cite high intergroup overlap and phenotypic plasticity as obstacles to using attribute groups for habitat assessment. A more direct approach would be to use physical (structural) attributes and relate these to river type.

Habitat attributes (RHS database)

CB plant communities are widespread in rivers with swift-moderate flows over predominantly stable sand, gravel and cobble substrate, with silt restricted to macrophyte beds and the margins. Two subtypes (CB1 and CB6a) occur over finer substrates in more or less clear, slow-flowing water. Watercourses characterised by *Callitricho-Batrachion* communities are likely to contain a diverse range of physical structure and habitats such as riffle-pool sequences, marginal deadwater, exposed riverine sediments, and side channels. Sections with bedrock or unstable gravel substrate are likely to be devoid of submerged plants. A dense tree canopy reduces light and plant biomass – such sites are likely to be bryophyte dominated.

Characterising watercourses with CB communities can be further developed using examples from the RHS database. This has been done for the habitat requirements of *Ranunculus p. penicillatus* in Northern

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***Ranunculus p. penicillatus* is associated with several different flows, from glides and pools to runs and riffles, though not with extremely fast-flowing water, such as in rapids, or in ponded areas.**

Ireland, and confirmed with supplementary fieldwork (ATEC 2001). The type of flow was demonstrated to be a significant factor: *Ranunculus p. penicillatus* was positively associated with runs, riffles, glides and pools, and negatively associated with rapids and ponded reaches. In addition, a strong correlation was observed with gravel-pebble substrate, and a negative correlation with bedrock substrate and shading.

RHS has also been used to investigate the relationship between macrophyte diversity and environmental variables using 51 reference sites in the Ribble catchment (Environment Agency 1999). Macrophyte diversity was correlated with high-energy flow conditions, increasing water width, and coarse bed and bank substrates. Modifications to the river (both physical structure and water quality) had a major effect in reducing macrophyte diversity – with water quality having a greater impact than river modification at the catchment scale.

Assuming both water quality and flow regime are satisfactory, geomorphological and physical features (including plant morphological groups) will indicate the quality and diversity of habitats in a watercourse. Habitat quality can be assessed on the basis of rare features, or a rare combination of features for sites of a particular river type. Using the RHS database it is possible to compare site habitat quality and modification with any other similar river type in the UK (Raven *et al.* 2000).

The value of the riparian zone should not be underestimated, particularly in relation to biodiversity, bank stability, protection from pollutants, and supply of coarse woody debris.

Ecological impacts

A simplified overview of the range of impacts affecting UK rivers and the typical vegetation community responses is provided in Table 5. These are of necessity generic and illustrate examples only: a far greater range of impacts and responses is possible.

Impacts may often occur in combination, so a change in plant community may reflect a number of causes. Although macrophytes are useful as indicators of physical and chemical conditions, they are not absolute indicators, as modified rivers can still support a representative channel community. In general, unmodified channels will have greater habitat diversity, and the diversity of channel macrophytes will reflect this (Bornette *et al.* 1998, 2001; Godreau *et al.* 1999).

Modified flow regime

Alterations to the drainage pattern and properties of catchments and subsequent changes in land use (intensive agriculture and forestry, urbanisation, reservoirs, etc.) have increased the flashiness of rivers by altering the shape of the natural hydrograph and reducing water retention time (Haslam 1997). This increases suspended solid loads and the levels of scouring, particularly if a watercourse is structurally modified. Headwaters and small streams are particularly vulnerable to changes in flow regime.

The present extent of wetland loss and catchment modification indicates

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The headwaters of chalk rivers, known as winterbournes, are particularly susceptible to drying up during periods of low flow.

Table 5. Summary of some of the main impacts affecting vegetation in British rivers, likely responses, and the communities most likely to be affected. Vulnerability varies across river types due to the influence of other environmental factors, or because the human impact in question is unlikely.

Impact	Response	Communities most often affected							Notes
		CB1	CB2	CB3	CB4	CB5	CB6 a	CB6 b	
Low flow	Increased silt deposition (Generally temporary in higher energy types)	✓	✓	✓	✓	✓	✓	✓	Includes natural climatic variation, and impacts due to abstraction and regulation. In some cases, 'low flow' may refer to the relative rarity of flushing flows sufficient to remove sediment
	Increase in emergent plants across channel.	✓	✓		✓		✓		
	Decrease in aquatic plant cover				✓	✓		✓	
	Margins invaded by terrestrial species			✓	✓	✓		✓	
	Phytoplankton blooms	✓							
	Increase in filamentous algae	✓	✓	✓	✓	✓	✓	✓	
Increased nutrients (accentuated during low flow)	Decrease in MTR	✓	✓	✓	✓	✓	✓	✓	MTR may not detect changes in all cases due to low species diversity, lack of sensitive species or flow constraints preventing invasion of 'eutrophic' species. In mesotrophic rivers *Ranunculus* may initially increase in biomass.
	Loss of nutrient-sensitive species	✓	✓		✓	✓	✓		
	Increase in *P. pectinatus*	✓	✓	✓					
	Increase in filamentous and epiphytic algae	✓	✓	✓	✓	✓	✓	✓	
Pollution: Herbicides	Loss of macrophytes, especially sensitive species	✓	✓	✓	✓	✓	✓	✓	Variable depending upon type of pollutant – extreme conditions will lead to total loss of macrophytes.
Pollution: Acidification	Loss of species characteristic of base-rich, lowland, eutrophic conditions					✓	✓	✓	Includes sedimentation and metals.
Pollution: Metal Pollution	Loss of species sensitive to high metal concentrations					✓	✓	✓	Aquatic plants contribute to purification of the system, so loss can exacerbate effects.
Channel modification (excluding rehabilitation)	Increase in emergent plants across channel	✓	✓		✓		✓		Includes over-widening, dredging, re-sectioning or impoundment downstream. Channel modifications generally cause flow to be more uniform, resulting in loss of species sensitive to flow. Weirs, dams and barrages may modify flow in more complex ways.
	Increased silt deposition	✓	✓	✓	✓	✓	✓		
	Reduction or loss of marginal species	✓	✓	✓	✓	✓	✓	✓	
	Loss of species sensitive to scour or fast flow (e.g. *Nuphar lutea*)			✓		✓	✓	✓	
	Loss of species sensitive to ponding or slow flows (e.g. *Ranunculus fluitans*)	✓	✓		✓				

management	community if management does not recognise the ecological requirements of all species.	✓	✓	✓	✓	✓	✓	✓	used to help to alleviate the extent of impact. *Ranunculus* can become mono-dominant if cut frequently (mainly an issue in CB2 and CB3). Marginal communities are often lost to bankside overgrazing or heavy cutting.
Tree cover – decrease	Reduction in bryophytes, increased growth of higher plants.	✓	✓	✓	✓	✓		✓	Small tree-lined streams tend to have a bryophyte dominated community. Lowland rivers have fewer bryophytes than uplands; CB1 has very few bryophyte spp.
Tree cover – increase	Increase in bryophytes, decreased growth of higher plants		✓		✓	✓	✓	✓	The aquatic macrophyte community of large rivers is not very vulnerable to these changes, as the trees are not large enough to shade the river completely. Smaller streams may develop tunnel vegetation dominated by bryophytes.
	Open grass/herb community replaced by woodland community	✓	✓	✓	✓	✓	✓	✓	
Introduced species	Modification to native plant community. If invasive, a reduction in diversity will occur, together with altered biological and fluvial processes.	✓	✓	✓	✓	✓	✓	✓	Riparian plant species are of the greatest concern nationally at present. Difficult to eradicate without repeated herbicide applications.
Trampling/grazing	Depending on the scale of activity, reduction in marginal vegetation cover, leading to increased erosion and sediment supply.	✓	✓	✓	✓	✓	✓	✓	Some local trampling is beneficial to maintain marginal diversity. Sheep and cattle grazing of banks is a widespread problem throughout Britain. In some chalk streams grazing by swans is considered problematic.

widespread disturbance to natural hydrological regimes in UK rivers. The impacts of abstraction and low flow on rivers are exacerbated in modified catchments with reduced water retention, and the effects are greatest at times of lowest flow. In addition to the loss of species associated with good flows (e.g. *Ranunculus*), emergent macrophytes will spread across low-energy channels, while silt deposition and nutrient retention increase (Brookes 1986, Wright & Berrie 1987). Conditions for epiphytic algae improve and this can cause a shift in community dominance (Wade *et al*. 2002).

Impounding rivers has the effect of altering plant communities, when species that thrive in stable flow depths, low velocities or finer substrates will be more likely to increase, at the expense of those requiring faster velocities and coarse substrates. In such circumstances, species such as *Sparganium emersum*, *Lemna* spp., *Potamogeton pectinatus* and *Nuphar* spp. may become dominant.

Abstraction and low flow

Abstraction and the increasing demand for water (particularly coupled with a more unpredictable climatic regime) are recognised as important issues requiring the implementation of new measures to protect rivers (Environment Agency 2001b). The timing of changes in water supply is important, as the season and extent of inundation is critical to the development of river plant communities in watercourses that are expected naturally to dry out for some time in most years (i.e. winterbournes; Holmes 1996).

Chalk streams and winterbournes (CB2 and perhaps some examples of CB4) are groundwater-fed systems, many of which have been affected by low flows and abstraction over the past 50 years (Wright & Berrie 1987; Wilby *et al*. 1998; Mainstone 1999). Winterbournes and headwaters subject to low flows will exhibit a decline in the extent and condition of *Ranunculus* species and an increase in macrophytes characteristic of slower flow, such as *Callitriche stagnalis* and *Rorippa nasturtium-aquaticum*. Marginal species, such as *Mentha aquatica* and *Myosotis scorpioides*, will increase in cover, and with longer periods of drying, this will lead to a transition to terrestrial grasses (Holmes 1996).

The more upland-influenced river types CB5 and CB6 tend to occur over impermeable geology, making them particularly susceptible to abstraction. As well as loss of wetted area, changes are likely to be manifested as loss of sensitive bryophyte species.

Substrate and the impact of silt

The problems of increased sediment loads and siltation have become widespread in many lowland rivers because of changing land-use practices, low flows and channel modification. In addition to the accumulation of deep silt deposits on the channel bed, increased sediment loading from the catchment will reduce the quality and quantity of available light. Silt-rich sediments retain nutrients and are likely to contain high levels of nitrogen and phosphorus (Mainstone *et al*. 2000), providing ideal conditions for the growth of benthic algae, which can hinder the spring growth of channel plants.

Plants growing in nutrient-rich sediments tend to have shorter shoots and weaker roots, and are therefore prone to washout during spates. The seeds of *Ranunculus* spp. do not survive in the anoxic conditions that develop within organic sediments, or are lost when the silt is flushed out by high flows (Mainstone 1999).

Aquatic plants are extremely effective at trapping suspended silt and increasing localised accumulation. Within *Ranunculus* beds, a cycle of silt deposition and erosion occurs through the season (Dawson 1979, 1989). In many small streams, water level and flow decreases through the summer and a reduction of *Ranunculus* growth coincides with encroachment by marginal herbs. Increased siltation in chalk streams can be a particular problem because of their limited natural flushing capacity. *Ranunculus* species are not able to vary their rooting level in response to increased silt, and become smothered.

The reduction of silt input at the catchment scale is essential to protect these systems (Woods & Armitage 1994). The organic content of silt will differ depending upon its source: point sources tend to produce organic silt and diffuse sources inorganic silt. During low summer flows, the proportion of point-source silt increases and nutrient-rich sediments can accumulate if winter flushing is low (Mainstone 1999).

Turbidity also has an impact on channel plant communities (Brookes 1986), and can cause a shift in species composition due to decreased light and the effects of abrasion. Increased turbidity (suspended solids) has been suggested as a possible reason for the decline of *Ranunculus fluitans* in some rivers in the Midlands (Preston & Croft 1997). Silt impacts can cause a serious loss of important habitat for other species (for example, spawning redds for salmonids and gravel beds for invertebrates) through smothering and in-filling of interstitial spaces. Rivers with degraded riparian habitat or lacking a buffer strip are particularly vulnerable to silt impact from storm run-off and cattle access to the channel.

In general, the physical habitat typified by *Callitricho-Batrachion* communities is one of clean substrate and swift to moderate flow. Except for the channel margins (and localised deposits associated with macrophytes) the substrate should be predominantly free of silt.

Diffuse pollution and eutrophication

Eutrophication has been recognised as a widespread problem in freshwater ecosystems (Environment Agency 2000) and while the issue of point-source pollution has been focused upon rivers covered by the Urban Waste Water Treatment Directive, diffuse pollution is seen as the next major issue in catchment management and water quality (Neal & Whitehead 2002). The process of eutrophication and its impact on macrophyte communities varies, depending upon river type and catchment. The effects of eutrophication on aquatic macrophytes are documented (Haslam 1978; Spink *et al*. 1993; Mainstone *et al*. 2000) as usually causing a shift in community composition and increased biomass. Increasing nutrient supply will lead to an overall reduction in the number of species, with a loss of *Ranunculus* spp. and an increase in pollution-tolerant species such as *Potamogeton pectinatus*, *Myriophyllum spicatum*, *Sparganium emersum*, *Schoenoplectus lacustris* and filamentous algae. More extreme nutrient increases lead to an overall impoverishment of the plant community, with algae dominating.

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Recent research on the River Kennet (above) has shown that, in the complex relationship between flow, water quality, epiphytes and *Ranunculus* species, flow is the most important variable affecting *Ranunculus* growth.

Mainstone (1999) provides a detailed account of the effects of eutrophication in chalk rivers and highlights the complex relationship between plant communities and algae. However, despite various attempts (e.g. Dawson *et al*. 1999; Schneider & Melzer 2003) it has been difficult to demonstrate a strong correlation between *Ranunculus* growth and water quality parameters that is not also confounded by the effects of other variables, particularly flow (Environment Agency 2001a; Demars & Harper 2002). This can partly be attributed to the combined effects of the main controlling factors (e.g. flow, light and temperature) masking the response to additional nutrient inputs. Increased summer flows decrease phosphorus levels (through dilution) and reduce epiphytic algae growing on *Ranunculus* plants.

The impact of fish farm effluent on both *Ranunculus* and periphytic algae was observed by Carr & Goulder (1990) with increased phosphorus levels in the plant tissue and an increase in algal growth. Higher levels of nitrate, ammonia and suspended solids also result in higher oxygen demand.

Ranunculus spp. respond rapidly to improved flow because of morphology and physiological adaptations that enable the plants to increase photosynthesis (Spink *et al*. 1990). The interaction between flow, *Ranunculus* growth, epiphytes and water quality is very complex – recent research on the River Kennet has revealed that, although increased nutrients can lead to thicker epiphytic covering with a subsequent decline in the condition of *Ranunculus* beds, flow is more important overall (Wade *et al.* 2002).

A five-year study of macrophyte status in the rivers Test and Itchen (Hampshire) clearly demonstrated the effects of low flows and water quality on the macrophyte community (Wilby *et al*. 1998). Although a strong relationship was observed between flow parameters and species distribution and abundance, there was a weak relationship for water quality parameters and plant cover, except for filamentous algae.

Changes in land use strongly influence both the duration and frequency of low flows and level of nutrient inputs. Whereas major point-source inputs from sewage treatment works are being curtailed through the Urban Waste Water Treatment Directive and the Asset Management Programme (AMP), there is evidence that indicates a widespread problem of diffuse pollution from agriculture and combined small point-source inputs in many catchments (Cooper *et al*. 2002, Jarvie *et al*. 2002). This research has described how, despite phosphorus stripping, conditions remain unsuitable for the biological community in relation to Environment Agency eutrophication guidelines (Environment Agency 2000). In addition, the potential for phosphorus retention and re-suspension from within bed sediment remains, and could be further compounded by an increased supply of nutrient-rich sediment due to changing land-use practices.

The majority of lowland headwater streams are affected by eutrophication from agricultural activities and rural sewage treatment works (Harper & Evans 1997), in addition to being physically degraded (Raven *et al*. 1998). Upland rivers have been shown to be more sensitive to small increases in phosphates (Mainstone *et al*. 2000). Channels with natural dynamics and a functional riparian strip are better able to cope with moderate increases in nutrients. The presence of coarse woody debris and leafy debris in the channel help to remove phosphorus.

Channel modification

River Habitat Survey data illustrate the scale and extent of physical modification to river channels in the UK (Raven *et al*. 1998). Modification includes major alterations like channel reinforcement, re-sectioning, and regulation, or smaller localised features such as bridges and current deflectors. Results from the RHS demonstrate that sites with extensive re-sectioning have increased silt, fewer riffles, point bars and bankside trees compared to unmodified channels (Raven *et al*. 2000). Upland sites tend be less extensively modified, although where such modification takes place its effect on the macrophyte community is often greater due to greatly increased levels of scour.

Channels with greater variation of water depth provide better habitat diversity compared to channels of uniform depth (Harper *et al*. 1999). In natural channels with a heterogeneous physical structure, macrophyte communities are distributed according to local flow conditions. Submerged fine-leaved macrophytes and mosses often occur in the faster water (>0.50 m s^{-1}), submerged broadleaved plants in deeper moderately fast water (approximately 0.40 m s^{-1}), and emergent macrophytes in slower water (<0–0.05 m s^{-1}).

Hey *et al*. (1994) studied the impact of flood alleviation schemes on river plant communities. The overall conclusions support the case that dredging, widening and straightening rivers reduces plant diversity. Although some severely modified channels support good beds of healthy *Ranunculus* spp. (for example through urban areas with concrete banks), the overall plant community is usually severely limited and species-poor.

Studies by Wright *et al*. (1992) and Harrison *et al*. (1999) clearly demonstrate the importance of marginal vegetation for macroinvertebrates and fish. Emergent plants and trailing terrestrial vegetation support high densities of invertebrates and different communities, illustrating the need to maintain diverse plant communities along river margins, and to maximise overall habitat heterogeneity with a mixture of riparian trees and open areas. In small streams, shading may be significant and may reduce algae and macrophyte growth in the channel, with the added benefits of reduced temperature, increased cover and inputs of organic debris.

The protective role provided by riparian vegetation is another important function. Simple measures such as fencing can have dramatic effects on both the riparian and channel communities. Soft engineering, for example using willows, is preferred to the common approach to bank protection taken in the past using sheet piling, concrete or gabion baskets.

Impact of introduced species

The impact of non-native invasive plants is a major concern due to their dominance over native species and resistance to control. Riverbanks provide ideal conditions for the arrival and spread of invasive plants such as Japanese knotweed (*Fallopia/Polygonum japonica*), Himalayan/Indian balsalm (*Impatiens glandulifera*), and giant hogweed (*Heracleum mantegazzianum*). These plants may not directly alter the composition of channel vegetation but certainly affect bankside vegetation, and can influence conditions instream through increased shading or siltation caused by greater bank erosion. Japanese knotweed will grow in river channels on exposed bars, and may alter local geomorphology as well as vegetation, possibly leading to localised flood events (e.g. River Teifi, N. Grieve, pers. obs.). In general, invasive species spread more rapidly and aggressively under disturbed conditions.

The problem aquatic species in ponds, ditches and canals – New Zealand swamp stonecrop (*Crassula helmsii*), floating pennywort (*Hydrocotyle ranunculoides*), parrot's feather (*Myriophyllum aquaticum*) and curly waterweed (*Lagarosiphon major*) – have not yet impacted flowing-water habitats. Although curly waterweed, is not known to cause a problem in rivers in the UK, it may have the potential to do so in the future, particularly as it occupies streams in its native country of South Africa. It has been observed growing (as an escapee from a garden pond) in a tributary of the River Teifi in Wales (N. Grieve, pers obs. 2001). Floating pennywort is already a serious pest in some ditch systems and has the potential to spread rapidly (NTH Holmes, pers. com.).

Catherine Duigan/CCW

The invasive Japanese knotweed competes with native species for space and nutrients, and can alter flow, possibly leading to flooding.

Canadian pondweed (*Elodea canadensis*) was first introduced in 1842 and is now naturalised in many rivers. By 1860 a 'Minister for *Elodea*' had been appointed, due to its profuse and problem growth in the UK canal networks. It has become displaced by Nuttall's water-thyme (*Elodea nutallii*) in some rivers and still-waters.

Free-floating aquatic species tend to be confined to static water, usually among emergent vegetation at the margins, or forming floating mats behind obstacles such as fallen trees. *Lemna minuscula* (formerly *L. minuta*) is widespread throughout the Hampshire Avon cSAC, but is confined to the marginal vegetation.

Introduced animals that occur predominantly in or along watercourses and may represent a threat to native plant species include North American signal crayfish (*Pacifastacus leniusculus*), now widespread throughout many rivers in England and parts of Wales. Signal crayfish consume large quantities of plant material in their native habitat; in some rivers they may have an impact on macrophyte communities.

The spread of new invasive species is increasing due to greater global transport and trade. It is likely that the relatively recent (1990s) outbreak of Phytophthora that now affects many riverside alders (*Alnus glutinosa*) was caused by the introduction of fungus with imported trees. The potential impact on riparian habitats is a cause for concern (Gibbs *et al*. 1999). Loss of alders could benefit aquatic plant communities through increased light availability. However, the loss of trees could also result in increased sedimentation through bank erosion, as the stabilising effect of the trees' root systems is lost.

River vegetation management

It is desirable from a habitat perspective to maintain a diverse macrophyte community, creating a mosaic of meso-habitats within the channel and providing a complex habitat structure (Hearne & Armitage 1994, Harper *et al*. 1999). This benefits not only the macrophyte community, but also the general ecosystem by providing a diverse habitat for invertebrates, fish and other aquatic organisms. Historically, management of river vegetation has mainly been undertaken to reduce flood risk and improve navigation and angling, and most lowland river systems have been deepened or dredged in the past to reduce the build up of silt deposits and increase channel capacity.

Channel vegetation

Aquatic plants growing in the channel are often managed by weed cutting, either on foot or using a boat. Herbicides, notably the diquat preparation Midstream, were formerly used, but the use of such herbicides in water courses has recently been banned by the European Commission.

The composition of CB vegetation is significantly altered by weed cutting, which causes the loss of sensitive species and a dramatic increase in resistant species. *Potamogeton* spp. seem to be particularly sensitive to weed cutting. A study of lowland Danish streams (Baatrup-Pedersen *et al*. 2002) demonstrated a loss of *Potamogeton natans* in cut areas and a dramatic increase in *Ranunculus peltatus* and *Sparganium* species. Community structure was also more diverse in uncut systems, with multi-layer patches and mixed communities being much more abundant. Wiegleb *et al*. (1991) noted a strong decline in seven of 12 *Potamogeton* species in the lower Saxony area due to disturbance, though this included impacts other than weed cutting. Chalk streams in Britain are heavily cut and usually lack *Potamogeton* spp., despite their apparent suitability for some of the less common species.

Chalk streams (a form of CB2) are probably the most extensively managed of rivers with CB communities. These low energy, base-rich systems maintain high flows and are thus capable of sustaining a diverse vascular plant community of considerable conservation importance. In these habitats CB vegetation, especially *R. penicillatus* ssp. *pseudofluitans*, grows abundantly, and indeed, instream macrophytes may play an important part in raising water levels by impeding flow through the system. Although weed cutting is often employed in these rivers, this may actually exacerbate the problem by encouraging vegetative growth. Left uncut, the biomass of a *Ranunculus* community decreases through self-shading and natural wash-out after flowering (Dawson 1979). Cutting before flowering can lead to increased *Ranunculus* beds during winter (Ham *et al*. 1982b), and cutting at the time of flowering is the most effective way to control summer growth.

Extensive mechanical weed-control operations may have other impacts. If entire populations of invertebrates are removed, then the ecological balance of the stream community will become disrupted as the loss of grazers may lead to an increase in epiphytic algae on submerged plants (Dawson *et al*. 1991). Armitage *et al*. (1994) recommend small-scale management to maintain the balance between conservation and the need to avoid flooding and create open areas for angling.

If possible, CB vegetation should be left uncut since this encourages greater species diversity; *Ranunculus* spp. will start to wash away naturally after flowering. A monoculture of *Ranunculus* spp. should not be considered favourable condition for CB habitat. If cutting is felt to be essential, good-practice guidelines include cutting *Ranunculus* vegetation in a checkerboard pattern to mimic natural patterns, maintain habitat diversity and sustain high water levels for floodplain habitats and to enable fishing (Mainstone 1999). Late-season cutting in the autumn is another option to reduce summer biomass (Dawson 1989). The use of herbicides in high-quality watercourses is not appropriate.

Bankside vegetation

Although CB communities focus primarily on the aquatic vegetation community, a healthy riparian fringe is often essential for its management. Bankside vegetation is very variable and may comprise almost anything from woodland to close-cropped grassland. In general, bankside vegetation is much more heavily managed than instream vegetation.

Bankside vegetation is most often managed by grazing, mowing, felling or other agricultural activities. Alongside chalk streams, mowing is widely used to create open areas for angling. On river SACs a diverse community of marginal and emergent vegetation should be encouraged; in particular, extensive areas of close-cropped turf adjacent to the river are disadvantageous as they encourage an increased input of silt, fertilizers, oil, pesticides and other pollutants into the river.

Nigel Holmes

Areas of close-cropped turf from grazing on a riverbank may result in increased input of pollutants such as silt, oil, fertilizers, pesticides and manure into the water.

Vegetation management can be used in a positive way to improve flows in modified channels, assist the removal of silt deposits, and reduce bank erosion. There is considerable potential to control the growth of aquatic macrophytes with the shading provided by bankside trees (Dawson & Kern-Hansen 1978), reducing the need for cutting and restoring the riparian zone.

Climate change

It is generally accepted that climate change is occurring on a global scale, and recent extreme weather patterns and storm events are a result of global warming. This has implications for river systems with their intimate links to the hydrological cycle. It is not yet understood whether the UK will become hotter and drier with less rainfall during longer summers, or windier and wetter with colder winters. There may be a change to more unpredictable swings from one weather pattern to another. Over the past decade (1990–2000) extremes in temperature, drought, gales and rainfall have been experienced. Climate change is important because many of the key processes concerning the attainment of favourable conservation status of CB communities are affected.

Rehabilitation

Many rehabilitation schemes have focused on increasing velocity in response to increased siltation and low discharge associated with past channel modification and over-abstraction. While this may benefit *Ranunculus* spp., channel narrowing may not be the most appropriate rehabilitation method for rivers with CB plant communities.

Fluvial geomorphological dynamics assessment can be used to study river processes at the catchment scale and provide an inventory of habitats. Such audits are particularly relevant to the management of watercourses and catchment impacts, and in providing a practical context for implementing rehabilitation methods (Harper *et al.* 1999). UK rivers supporting Habitat 3260 can also be related to RHS benchmark sites for comparison of flow and substrate types, Habitat Quality Assessment (HQA) and Habitat Modification Score (HMS). Coverage of benchmark sites is sufficiently comprehensive to allow comparisons at both national and regional scales, for all river types.

Channels that are over-widened or over-deepened have reduced habitat diversity compared to those with natural dimensions (Hey *et al.* 1994). The relationship between perturbations to the physical river channel and width-depth parameters enables predictions of the expected number and type of functional habitats to be made (Harper *et al.* 1999). These are compatible with habitat features recognised by RHS and enable the identification of target features and desired conditions for restoration/rehabilitation. Many small-scale channel rehabilitation schemes have focused on restoring riffles, or narrowing channels to alleviate low flows, but these do not restore the functioning dynamics of a river, or recognise the processes that link various river components.

Simple measures such as providing bankside fencing have been shown to produce dramatic alterations to bankside stability, silt inputs, and marginal and channel vegetation. The functional habitat approach has a great deal of practical application to managing and rehabilitating watercourses. Harper & Everard (1998) outline the rationale behind this approach and advocate the use of a holistic management regime to restore natural dynamics and connectivity throughout a river system. Examples of channel enhancement and restoration methods are provided in RSPB *et al.* (1994). In addition, River Restoration Centre (1999) provides useful case studies and illustrations.

It is essential that the aims of rehabilitation are properly understood for any particular river and that data have been collected on hydrology and geomorphology before planning a rehabilitation programme. Upland rivers with higher energy and sediment transport will require a different approach to lowland channels where natural solutions and soft engineering techniques may be more appropriate.

Setting objectives

Site-specific conservation objectives are being developed for each SAC river in the UK. A checklist of the key habitat and community attributes indicative of habitat condition is shown below:

Table 6. Generic indicators of habitat quality in CB rivers. HQA and HMS are measures derived from River Habitat Survey (RHS): HQA = Habitat Quality Assessment; HMS = Habitat Modification Score.

4 or more vegetation components present, depending on target community.	3 or fewer vegetation components present
CB communities present	Increased emergent community or algal cover
Natural riparian community present	Riparian community damaged or destroyed
Natural dynamics (geomorphology)	Modified dynamics (loss of channel diversity)
Extensive run/riffle/glide flow types (not CB1 or CB6a)	Static or slow-flow type dominant (not CB1 or CB6a)
Extensive stable cobble/pebble/gravel substrate	Extensive silt (not CB1)
No modification of channel or banks	Extensive modification of channel or banks
High HQA	High HMS
Healthy *Ranunculus* (if a common component of the CB community)	Stressed *Ranunculus*
Typical assemblage and diversity	Extensive *Potamogeton pectinatus*
	Extensive emergent vegetation in channel
	Extensive epiphytic/filamentous algae
	Several non-native plant taxa
High MTR scores (relative to type)	Low MTR scores (relative to type)

Defining favourable conservation status

Rivers are essentially dynamic habitats, and macrophytes can respond to changes in solar radiation, flow, and nutrient inputs very rapidly in the growing season, with large inter-annual variation in composition and abundance (Wright *et al*. 2002). This will be reflected in wide differences in perceived condition from year to year. Condition assessment will therefore be based on a picture built up from the results of monitoring the following elements over time.

- Vegetation should be characteristic for river type. Extensive filamentous and epiphytic (diatomaceous) algae indicate unfavourable condition.
- Channels should be characteristic for JNCC river type – assessed using fluvial audit and the reference sites in the RHS database, with HQA and HMS values providing a measure of quality and modification.
- Flow should be characteristic for the catchment type – as a guideline at least 90% of the naturalised daily mean flow should be maintained. Typically, the predominant flow should include run, riffle, and glide (with marginal deadwater and pools in the correct proportion for river type).
- Channel substrate should be predominantly free of silt (not CB1 or CB6a) – typically, the predominant substrate should include cobbles, pebbles, and gravel. More frequent and detailed monitoring of silt and suspended solids may be required where specific problems are known or suspected to occur.

Assuming that physical structure, water quality and quantity are satisfactory, the diversity and abundance of the plant community is likely to indicate favourable conservation status. Monitoring programmes will need to address the condition of the channel, banks, riparian zone and dynamics of river processes, in addition to the macrophyte community.

There are currently several projects looking at harmonising data collection and use – for example, SERCON 2 (Boon 2001) in the UK and the STAR project in the EU. For the UK, collaboration between government agencies will be essential to assess the conservation status of Habitat 3260 across its natural geographical range.

Summary of research requirements

Further research is needed to determine typical CB community dynamics and response to change, habitat partitioning between macrophytes, life history strategies, macrophyte and epiphyte interactions, fluvial and sediment nutrient dynamics. Without this information it is often difficult to untangle the relationship between habitat and macrophyte communities and environmental variables. With advances in the understanding of aquatic ecology and the development of landscape ecology, GIS technology and databases such as RHS and SERCON 2, the management of watercourses can be better integrated, recognising catchment processes and connectivity.

A great deal of research needs to be undertaken to more precisely quantify many of the key interactions described in this report. The main priorities are to:

- Test the CB classification and its workability in relation to the breadth of rivers included within each CB type, the proposed indicator species and the extent to which these are affected by environmental factors.
- Develop compatible databases for community type and habitat features. Establish monitoring programmes for SACs within a wider framework to assess the conservation status of the feature across its range in the UK.
- Test 'key attributes' as indicators of condition.
- Investigate the dynamic interactions of macrophytes within the community under different conditions and impacts. Use this information to develop best-practice guidelines for the management and restoration of vegetation.
- Determine the effects of past widening and deepening of watercourses in relation to geomorphology/habitats affecting macrophyte growth and distribution. Develop guidelines for the rehabilitation of different river types.
- Investigate the spread and extent of non-native species as part of the channel community.

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Appendix A: Macrophyte groups and species used in the determination of CB plant communities

Bryophytes	*Amblystegium fluviatile* (Hedw.) Bruch, Schimp. & WGümbel
	Blindia acuta (Hedw.) Bruch, Schimp. & W.Gümbel
	Brachythecium plumosum (Hedw.) Bruch, Schimp. & WGümbel
	Brachythecium rivulare Bruch, Schimp. & WGümbel
	Chiloscyphus polyanthos (L) Corda
	Cinclidotus fontinaloides (Hedw.) P.Beauv.
	Dichodontium flavescens (Dicks.) Lindb.
	Dichodontium pellucidum (Hedw.) Schimp.
	Dicranella palustris (Müll.Hall.) Schimp.
	Fontinalis antipyretica Hedw.
	Fontinalis antipyretica var. *gracilis* (Hedw.) Schimp.
	Fontinalis squamosa Hedw.
	Hygrohypnum luridum (Hedw.) Jenn.
	Hygrohypnum ochraceum (Turner ex. Wilson) Loeske
	Hyocomium armoricum (Brid.) Wijk & Margad.
	Jungermannia atrovirens Dumort. agg.
	Amblystegium riparium (Hedw.) Warnst. (= *Amblystegium riparium*) (Hedw.) Bruch, Schimp. & WGümbel
	Marsupella emarginata (Ehrh.) Dum.
	Nardia compressa (Hook.) Gray
	Nardia scalaris Gray
	Pellia endiviifolia (Dicks.) Dumort.
	Pellia epiphylla (L.) Corda
	Philonotis fontana (Hedw.) Brid.
	Racomitrium aciculare (Hedw.) Brid.
	Rhynchostegium riparioides (Hedw.) Cardot
	Scapania gracilis Lindb.
	Scapania spp.
	Scapania subalpina (Nees ex Lindenb.) Dumort.
	Scapania undulata (L) Dumort.
	Schistidium rivulare (Brid.) Podp. (= *S. alpicola* (Hedw.) Limpr. var. *rivulare* (Brid.) Limpr.)
	Sphagnum L. spp.
	Thamnobryum alopecurum (Hedw.) Gang.
Starworts	*Callitriche hamulata* Kütz. ex. WDJ Koch
Callitriche	*Callitriche hermaphroditica* L
	Callitriche obtusangula Le Gall
	Callitriche platycarpa Kütz.
	Callitriche L spp (unidentified)
	Callitriche stagnalis Scop.
Marginals	*Apium nodiflorum* (L) Lag.
	Berula erecta (Huds.) Coville
	Butomus umbellatus L.
	Menyanthes trifoliata L.
	Oenanthe aquatica (L) Poir.
	Oenanthe fluviatilis (Bab.) Coleman
	Rorippa nasturtium-aquaticum agg. (L.) Hayek *sensu lato*
Milfoils	*Myriophyllum alterniflorum* DC
	Myriophyllum spicatum L
	Myriophyllum verticillatum L
Others	*Ceratophyllum demersum* L
	Ceratophyllum submersum L
	Chara L spp.
	Chara vulgaris L

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Life in UK Rivers was established to develop methods for conserving the wildlife and habitats of rivers within the Natura 2000 network of protected European sites.

Set up by the UK statutory conservation bodies and the European Commission's LIFE Nature programme, the project has sought to identify the ecological requirements of key plants and animals supported by river Special Areas of Conservation.

In addition, monitoring techniques and conservation strategies have been developed as practical tools for assessing and maintaining these internationally important species and habitats.

Ranunculion fluitantis and *Callitricho-Batrachion* vegetation communities provide a stunning display in European rivers, and serve as important habitat for invertebrates and fish. These assemblages of aquatic plants also influence flow, nutrient and sediment dynamics in freshwater ecosystems.

However, across Europe, river plant diversity is declining at an alarming rate. This is due to factors such as nutrient enrichment, siltation, over-abstraction and unfavourable management practices.

This report describes the ecological requirements of watercourses characterised by *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation communities in a bid to assist the development of monitoring programmes and conservation strategies that are vital for their future.

Information on Conserving Natura 2000 Rivers and Life in UK Rivers can be found at **www.riverlife.org.uk**

This document was produced with the support of the European Commission's LIFE Nature programme and published by Life in UK Rivers – a joint venture involving English Nature, the Countryside Council for Wales, the Environment Agency, the Scottish Environment Protection Agency, Scottish Natural Heritage and the Scotland and Northern Ireland Forum for Environmental Research.