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# *A revised classification system for British rivers based on their aquatic plant communities*

N.T.H. HOLMES[a,*], P.J. BOON[b] and T.A. ROWELL[c]
[a] *Alconbury Environmental Consultants, 57 Ramsey Road, Warboys, Cambs PE17 2RW, UK*
[b] *Scottish Natural Heritage, 2 Anderson Place, Edinburgh EH6 5NP, UK*
[c] *Countryside Council for Wales, Plas Grogerddan, Aberystwyth, Ceredigion SY23 3EE, UK*

ABSTRACT

1. This paper describes a classification of British rivers based on their aquatic plant communities, and represents a revision of an earlier version published in the early 1980s.
2. Data on macrophytes from 459 riverine sites were added to the original database of 1055 sites, and analysed using TWINSPAN (Two-Way Indicator Species Analysis).
3. The overall structure of the new classification is the same as the first version. The highest level consists of four broad groups (A–D) representing an environmental gradient from lowland eutrophic rivers, to those that are essentially upland, torrential and oligotrophic. These four groups are divided into 10 River Community Types (RCTs) with further sub-divisions into 38 sub-types. For many sites, their allocation to a particular RCT has remained unchanged; other sites have been reassigned and this process has helped remove some of the minor anomalies in the previous system.
4. The results have confirmed that aquatic macrophytes are a valuable tool for classifying rivers, and suggest that in the absence of natural stress or human impact most communities are sufficiently robust to remain stable over time.
5. The original system has been used extensively over the past 15 years, particularly for nature conservation assessment. New applications include trophic ranking techniques for water quality monitoring, and the integration of the botanical classification within a broader system for conservation evaluation. It is intended that in future the classification will be extended to incorporate rivers in Northern Ireland, thus creating a system applicable to the whole of the UK.


KEY WORDS: river classification; macrophytes; SSSIs; conservation; plant communities

## INTRODUCTION

Many rivers throughout the world have been the subject of biological surveys, often with the aim of water quality assessment, and only rarely to develop river classifications. This paper describes the development of a classification system for British rivers, based on their aquatic plant communities, principally for the

* Correspondence to: Alconbury Environmental Consultants, 57 Ramsey Road, Warboys, Cambs PE17 2RW, UK.

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purpose of conservation assessment (Boon, 1995). It outlines the survey protocol, development and testing of the classification, and describes some of the uses of the system.

Assessments of river conservation value require a classification framework so that rivers can be compared in the light of their particular geographical or geological setting. It is then easier to determine what are vulnerable, declining or scarce resources and assign priorities for their protection. Such classifications must take account of the range of physical and biological properties of rivers, and the manner in which they change downstream, as this is critically important in determining management policies (Hawkes, 1975). The extent of change varies from river to river, and is related to the scale at which it is observed. For example, it is inordinately greater in the Amazon compared with the Thames, the former rising high in the Andes before flowing through tropical rain forest to the Pacific Ocean, and the latter rising on low-altitude limestone hills before meandering through London to discharge one three-thousandth of the Amazon's flow to the English Channel. Whilst the Thames shows comparatively little change from source to mouth in an international context, it shows modest change in a national (British) context, and considerable hydrological and ecological change in a regional context.

River classification systems have been reviewed by several authors (e.g. Hawkes, 1975; Naiman *et al*., 1992) and vary from those based on hydrology or geomorphology (e.g. Strahler, 1957; Schumm, 1977; Gordon *et al*., 1992) to those derived from the distribution of particular groups of organisms such as fish (e.g. Huet, 1949, 1959) or invertebrates (e.g. Carpenter, 1928). However, until comparatively recently much of the work was focused on downstream changes *within* rivers, which were either viewed as a series of discrete zones, or as a continuum (Vannote *et al*., 1980). Classification systems that range more broadly across a local region or an entire country are a more recent development. This is largely due to progress in computer technology and statistical packages which can process large datasets, distinguishing groups of sites on the basis of similarity in their characteristics. For example, techniques such as TWINSPAN (Two-Way Indicator Species Analysis: Hill, 1979a) and DECORANA (detrended correspondence analysis: Hill, 1979b) have frequently been used to erect classifications both for rivers and lakes (e.g. Wright *et al*., 1989; Foster *et al*., 1992; Palmer *et al*., 1992).

Most classifications of plant communities rely on phytosociology (Braun-Blanquet, 1932; Tuxen, 1968; Rodwell, 1991), but taxonomic complications of river macrophyte communities make it difficult to recognize consistent associations to fit the conventions of phytosociologists (Den Hartog and Segal, 1969; Hynes, 1970; Westlake, 1975). The most extensive survey and review of macrophytes in European rivers was undertaken by Haslam (1987), mainly during the 1970s. A standard procedure was followed in which observations were made of submerged, floating and emergent plants within the channel, recording presence, relative abundance and cover. Haslam recognized the importance of downstream changes in river plant communities and gave detailed accounts of species associated with different 'stream types', such as 'mountainous', 'upland' , 'lowland chalk', 'lowland sandstone', and 'lowland and upland clay'.

In some parts of Europe, far more detailed surveys of macrophytes have been carried out in particular regions or catchments. Very few have been used for classification purposes but are descriptive studies of downstream floristic changes frequently noting the impact of deteriorating water quality or habitat degradation. There are many examples of such studies in Germany (e.g Krause, 1971; Weber-Oldecop, 1972; Grube, 1975; Kohler, 1975; Wiegleb, 1984) and Finland (Sirjola, 1969).

In Britain, pioneering studies of river macrophytes during the 1920s were used to develop a rudimentary classification relating aquatic plants to physical variables such as substrate and water velocity (Butcher, 1933). (Butcher appears to have been one of the first to use macrophytes in river classification, although at about the same time Ricker (1934) included them in broad descriptions of Ontario rivers.) Later surveys by others confirmed many of these species/habitat associations (e.g. Haslam, 1978), and the spatial (e.g. Holmes and Whitton, 1975, 1977a,b) or temporal (e.g. Westlake, 1981; Ham *et al*., 1982) succession of communities.

 

It was not until the 1980s that attempts were made to develop a comprehensive national river classification for England, Wales and Scotland based on macrophytes. River surveys throughout Britain were commissioned by the Nature Conservancy Council (NCC) between 1978 and 1982, and the resulting classification system (Holmes, 1983, 1989; Department of the Environment, 1987) used for various purposes such as in selecting rivers as statutory conservation sites (Nature Conservancy Council, 1989; Boon, 1995). However, it was recognized from the outset that further work was needed on the stability of plant communities over time, the effects on accuracy when different surveyors were used, and on community associations with external environmental variables. Moreover, some parts of Britain were not well represented in the survey and with the addition of new sites it was likely that the classification itself would need to be revised.

## METHODS

### Field survey

Between 1978 and 1982, 1055 sites on more than 200 rivers were surveyed by a single surveyor. A new survey programme was carried out from 1988 to 1991, which, together with some additional work by one of the authors (NTHH), provided data from a further 459 sites for revising the classification. Unlike the earlier survey, the later ones were completed by at least six different people. All surveys were carried out on systems which were considered by nature conservation bodies to have, as a minimum, a reasonably intact macrophyte community. Rivers believed to contain important plant communities (e.g. in terms of rarity or species richness) were also included in the survey.

The same method was used throughout, and this has now become a standard technique for surveying macrophytes in British rivers. Further details are given in Holmes (1983, 1989), Department of the Environment (1987) and Boon *et al*. (1996). In essence the survey involved recording macrophytes at sites 1 km long (formed from two contiguous 500 m lengths), situated 5–7 km apart (closer together for small rivers, further apart for larger ones). Survey was carried out by wading, walking the banks, or from a boat for deeper, wider rivers. A standard check-list was used for plant recording, containing 223 taxa (most at the species level), with the absence of a taxon as significant as its presence. Rarer aquatic plants found at the site, but not included on the check-list, were recorded but to ensure standardization only check-list taxa were used in the classification process.

Surveys included the entire channel and lower slopes of the banks, with separate records being made for macrophytes that occurred more or less permanently submerged (river taxa), and those typically subject to alternate inundation and exposure with the rise and fall of river levels (bank taxa). Terrestrial plants with no special affinity to rivers were excluded from the survey. At each site an estimate was made of relative macrophyte abundance (1, rare; 2, occasional or frequent; 3, abundant or dominant) and cover (1, $<0.1\%$; 2, 0.1–5%; 3, $>5\%$). Field data were gathered on other features such as river flow types, substrates, width, depth, and landuse, while map-derived data on geology, altitude, and gradient were assembled for studying the relationship between environmental variables and plant communities.

### Data analysis

The enlarged dataset was subjected to the same analysis as the previous one (Department of the Environment, 1987) using TWINSPAN (Hill, 1979a) to derive a classification of plant communities and a list of taxa indicative of each site cluster. The classification is based on combined data for both river and bank taxa from the two 500 m lengths, with the highest abundance figure used. All rare species ($<5$ occurrences) were excluded from the final analysis.

 

## RESULTS

The first version of the classification consisted of a three-tier hierarchy, the highest level containing four groups (A, B, C and D) divided into 10 River Community Types (RCTs) (I–X), with further sub-divisions into 56 end-groups (Holmes, 1983; Department of the Environment, 1987). Figure 1 illustrates the relationship between groups, RCTs and end-groups and shows that disproportionate numbers of sites were allocated to the four groups.

The revised classification has a similar three-tier structure, retaining the same four broad Groups A–D and the 10 RCTs, but defining only 38 sub-types instead of the 56 end-groups of the original system (Table 1). (The decision on how many sub-types to include is arbitrary, and is related principally to pragmatic factors such as the ability of experienced surveyors to recognize sub-types in the field.) As in the previous analyses of the data, the revised classification is based solely on the similarities of the flora recorded rather than on relationships between plant taxa and habitat variables.

The distribution of sites in Groups A–D is shown in Figure 2, with site distributions for RCTs I–X shown in Figures 3–6. The database and TWINSPAN outputs have also been used to explore the relationship between groups, RCTs and sub-types and some of the environmental variables thought to affect macrophyte distribution in rivers. Summary data on the physical characteristics of sites are given in Table 2 (Groups A–D) and Table 4 (RCTs I–X), and data on characteristic species are given in Table 3 (Groups A–D) and Table 5 (RCTs I–X). More detailed information is presented in Holmes *et al.* (in press).

### Descriptions of Groups A–D

Holmes (1989) described Groups A, B, C and D in the original classification in terms of a spectrum of floral communities from those typical of lowland, eutrophic rivers (Group A) to those typical of torrential, oligotrophic waters (Group D). In general, the characteristics of the four groups in the revised classification are the same. However, the previous descriptions of the physical features of sites in Groups

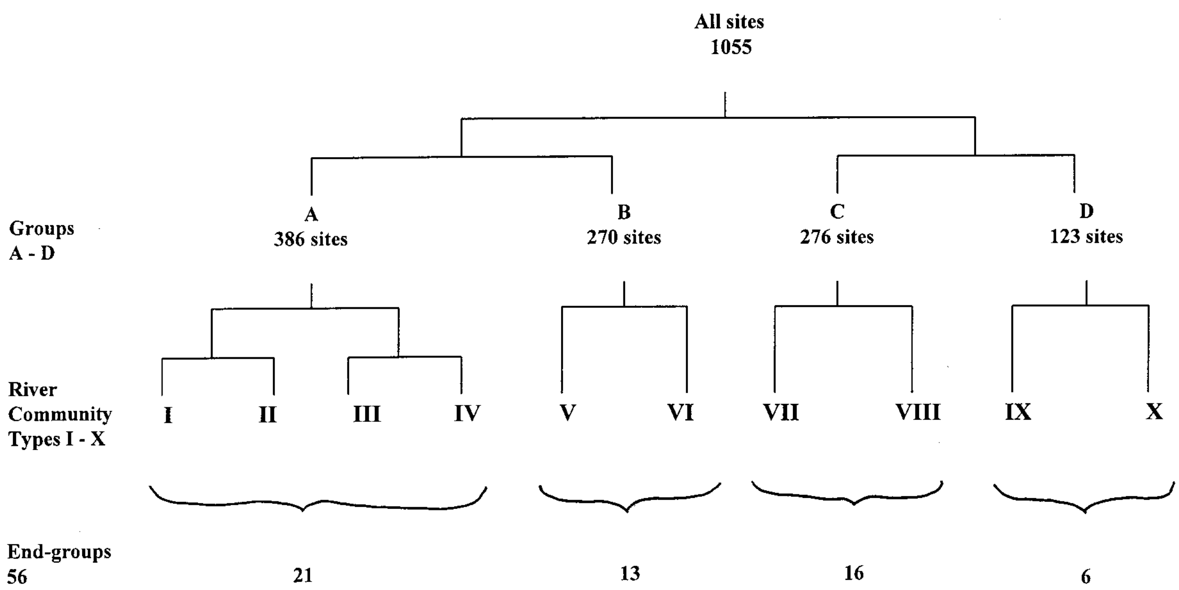


Figure 1. The original TWINSPAN classification of 1055 riverine sites throughout Britain into four groups (A–D), 10 River Community Types (I–X), and 56 end-groups.

Table 1. Relationship between the four groups (A–D), 10 River Community Types (RCTs) and 38 sub-types

| Group | RCT | No. of sites | Sub-types | No. of sites |
|---|---|---|---|---|
| A | I | 102 | Ia | 18 |
| | | | Ib | 23 |
| | | | Ic | 61 |
| | II | 164 | IIa | 54 |
| | | | IIb | 71 |
| | | | IIc | 39 |
| | III | 90 | IIIa | 19 |
| | | | IIIb | 71 |
| | IV | 119 | IVa | 86 |
| | | | IVb | 17 |
| | | | IVc | 16 |
| B | V | 195 | Va | 45 |
| | | | Vb | 69 |
| | | | Vc | 24 |
| | | | Vd | 26 |
| | | | Ve | 31 |
| | VI | 202 | VIa | 32 |
| | | | VIb | 29 |
| | | | VIc | 68 |
| | | | VId | 53 |
| | | | VIe | 20 |
| C | VII | 76 | VIIa | 13 |
| | | | VIIb | 23 |
| | | | VIIc | 18 |
| | | | VIId | 22 |
| | VIII | 247 | VIIIa | 36 |
| | | | VIIIb | 73 |
| | | | VIIIc | 44 |
| | | | VIIId | 39 |
| | | | VIIIe | 55 |
| D | IX | 90 | IXa | 19 |
| | | | IXb | 25 |
| | | | IXc | 46 |
| | X | 229 | Xa | 75 |
| | | | Xb | 22 |
| | | | Xc | 48 |
| | | | Xd | 32 |
| | | | Xe | 52 |

A–D were based on subjective assessments (Holmes, 1989), whereas new analyses of the data support the earlier descriptions with firm evidence. They also provide confirmation of the classification of Butcher (1933) which was linked to characteristics such as geology, channel gradient, altitude, substrate, and current velocity.

The information given in Table 2 confirms a transition from Group A to D with respect to the altitude of sites surveyed, and the height at which rivers rise. There is a clear gradation of mean site altitude with Group B 50% higher than A, C 40% higher than B, and D a further 30% higher than C. Approximately

 

Table 2. Physical characteristics of sites in Groups A–D. Results relate to combined information for all sites assigned to each of the four groups

| Group characteristics | A | B | C | D |
|---|---|---|---|---|
| Geology (% occurrence at sites) | | | | |
| Calcareous clay | 29 | | | |
| Non-calcareous clay | 13 | | | |
| Chalk | 22 | | | |
| Hard limestone | | 17 | 14 | 10 |
| Soft sand | 12 | 24 | | |
| Hard sandstone | | 23 | 17 | 16 |
| Calcareous shale | | | | |
| Non-calcareous shale | | | 30 | 10 |
| Hard rock | | | | 50 |
| Height at source (m) | | | | |
| Mean | 138 | 376 | 467 | 442 |
| Min | 10 | 30 | 20 | 10 |
| Max | 700 | 761 | 1210 | 1210 |
| Altitude of site (m) | | | | |
| Mean | 49 | 74 | 125 | 160 |
| Min | 0 | 5 | 5 | 0 |
| Max | 213 | 250 | 425 | 750 |
| Slope (km per 15 m fall) | | | | |
| Mean | 15 | 8.6 | 4.9 | 2.7 |
| Min | 0.3 | 0.1 | 0.2 | 0.1 |
| Max | 25 | 25 | 25 | 25 |
| Substrates (% occurrence at sites) | | | | |
| Silt | 44 | 11 | 8 | 13 |
| Sand | 20 | 11 | 8 | 8 |
| Clay | 41 | 6 | 2 | 2 |
| Gravel | 52 | 27 | 21 | 19 |
| Pebble | 17 | 47 | 42 | 36 |
| Cobble | 4 | 52 | 63 | 60 |
| Boulder | 0.4 | 26 | 45 | 56 |
| Bedrock | 0.2 | 9 | 19 | 33 |
| Flow types (% occurrence at sites) | | | | |
| Pool | 5 | 9 | 5 | 13 |
| Slack | 89 | 84 | 67 | 46 |
| Riffle | 5 | 10 | 14 | 42 |
| Run | 40 | 68 | 71 | 49 |
| Rapid | 0.8 | 8 | 35 | 49 |
| Width (m) (% occurrence at sites) | | | | |
| $<5$ | 33 | 24 | 28 | 50 |
| 5–10 | 38 | 30 | 42 | 41 |
| $>10$–20 | 36 | 38 | 37 | 29 |
| $>20$ | 15 | 32 | 24 | 17 |
| Depth (m) (% occurrence at sites) | | | | |
| $<0.25$ | 45 | 75 | 80 | 73 |
| 0.25–0.5 | 49 | 52 | 42 | 52 |
| $>0.5$–1 | 29 | 8 | 9 | 24 |
| $>1$ | 30 | 15 | 11 | 11 |

Table 3. Percentage frequency of occurrence of the 30 most common taxa present within the sites assigned to each of the four groups (A–D)

| Taxa | Group | | | |
|---|---|---|---|---|
| | A | B | C | D |
| *Apium nodiflorum* | 74 | | | |
| *Scrophularia auriculata* | 72 | | | |
| *Nasturtium officinale* | 78 | | | |
| *Glyceria maxima* | 64 | | | |
| *Callitriche stagnalis* | 61 | | | |
| *Sparganium emersum* | 59 | | | |
| *Juncus inflexus* | 58 | | | |
| *Lemna minor* | 55 | | | |
| *Lythrum salicaria* | 54 | | | |
| *Polygonum amphibia* | 51 | | | |
| *Lycopus europaeus* | 51 | | | |
| *Carex riparia* | 50 | | | |
| *Veronica anagallis-aquatica* | 47 | | | |
| *Symphytum officinale* | 47 | | | |
| *Nuphar lutea* | 47 | | | |
| *Carex acutiformis* | 47 | | | |
| *Veronica beccabunga* | 81 | 63 | | |
| *Solanum dulcamara* | 84 | 59 | | |
| *Epilobium hirsutum* | 92 | 65 | | |
| *Sparganium erectum* | 91 | 77 | | |
| *Cladophora glomerata* agg. | 69 | 77 | | |
| *Vaucheria* sp.(p.) | 68 | 61 | | |
| *Elodea canadensis* | 54 | 47 | | |
| *Phalaris arundinacea* | 97 | 94 | 73 | |
| *Myosotis scorpioides* | 93 | 78 | 60 | |
| *Mentha aquatica* | 82 | 84 | 68 | |
| *Hildenbrandia rivularis* | | 56 | | |
| *Oenanthe crocata* | | 53 | | |
| *Amblystegium riparium* | | 52 | | |
| *Brachythecium rutabulum* | | 47 | | |
| *Agrostis stolonifera* | 96 | 98 | 95 | 59 |
| *Salix* sp.(p.) | 84 | 86 | 84 | 61 |
| Trees | 78 | 89 | 83 | 53 |
| *Filipendula ulmaria* | 66 | 68 | 67 | 41 |
| *Rhynchostegium riparioides* | | 89 | 95 | |
| *Verrucaria* sp.(p.) | | 80 | 71 | |
| *Amblystegium flaviatile* | | 65 | 54 | |
| *Conocephalum conicum* | | 64 | 53 | |
| *Equisetum arvense* | | 58 | 49 | |
| *Lemanea fluviatilis* | | 48 | 54 | |
| *Fontinalis antipyretica* | | 87 | 80 | 46 |
| *Juncus acutiflorus* | | 67 | 74 | 59 |
| *Glyceria fluitans* | | 57 | 68 | 49 |
| *Juncus effusus* | | 55 | 71 | 83 |
| Filamentous green algae | | 52 | 76 | 71 |
| *Caltha palustris* | | 51 | 66 | 47 |
| *Chiloscyphus polyanthos* | | | 68 | |
| *Fontinalis squamosa* | | | 57 | |
| *Hygrohypnum ochraceum* | | | 56 | |
| *Angelica sylvestris* | | | 51 | |

 

Table 3. Continued

| Taxa | Group A | Group B | Group C | Group D |
|---|---|---|---|---|
| *Brachythecium rivulare* | | | 49 | |
| *Schistidium alpicola* | | | 48 | |
| *Pellia epiphylla* | | | 67 | 83 |
| *Ranunculus flammula* | | | 58 | 74 |
| Ferns | | | 54 | 60 |
| *Deschampsia cespitosa* | | | 51 | 51 |
| *Sagina procumbens* | | | 46 | 41 |
| *Juncus bulbosus* | | | | 78 |
| *Racomitrium aciculare* | | | | 72 |
| *Anthroxanthum oderatum* | | | | 70 |
| *Carex nigra* | | | | 70 |
| *Potentilla erecta* | | | | 59 |
| *Sphagnum* spp. | | | | 59 |
| *Scapania undulata* | | | | 58 |
| *Viola palustris* | | | | 57 |
| *Molinea caerulea* | | | | 54 |
| *Polytrichum commune* | | | | 54 |
| *Nardus stricta* | | | | 47 |
| *Galium palustris* | | | | 45 |
| *Carex demissa* | | | | 43 |
| *Achillea ptarmica* | | | | 41 |
| *Bryum pseudotriquetrum* | | | | 38 |

85% of rivers in Group A rise at altitudes below 200 m compared with 15% for Group D; Group B is intermediate but source altitudes for Group C sites are closer to those in Group D. Sites with low gradients are most common in Group A whilst those with steep gradients prevail in Group D.

Underlying geology is clearly a major factor in discriminating between the four groups. In Group A, clay, chalk, and soft sands predominate. In Group B, hard and soft sandstone dominate but with hard limestone also prominent. For Group C, non-calcareous shales are the most common geological feature whilst for Group D, hard rocks such as granite, igneous rocks, other metamorphic rocks and schists are all more prevalent than in other groups.

Communities in Group A are dominated by vascular plants and contain many more aquatic species than the other groups. Communities in Group B occur where sediments are less rich than in Group A but comprise sands, gravels, pebbles and cobbles because water velocity is greater due to their steeper gradient. Group C communities typically occur where water velocity is much higher than at sites in either A or B, and substrates are predominantly composed of rocks and boulders. Group D communities occur at sites with higher altitudes, steep gradients, boulder-strewn substrates, and with rapidly flowing water.

Of the most commonly occurring taxa in the four groups only four are represented in all groups: willow species, other trees, *Agrostis stolonifera* and *Filipendula ulmaria* (Table 3). Apart from these, no common taxa in Group A have any affinity to Group D and only the widespread *Phalaris arundinacea*, *Myosotis scorpioides* and *Mentha aquatica* have affinity with Group C.

Rather more taxa are common to Group A and its nearest neighbour, Group B: *Veronica beccabunga*, *Solanum dulcamara*, *Epilobium hirsutum*, *Sparganium erectum*, *Elodea canadensis*, *Cladophora glomerata* agg. and *Vaucheria* spp. There are 16 taxa listed in Table 3 which are strongly associated only with Group A communities. These are all vascular plants, some submerged (e.g. *Sparganium emersum*), some floating (e.g. *Lemna minor*), some emergent (e.g. *Veronica anagallis-aquatica*) and many bankside species (e.g.

 


Figure 2. The location of sites in Groups A–D.

 


Figure 3. The location of sites in RCTs I–IV (Group A).

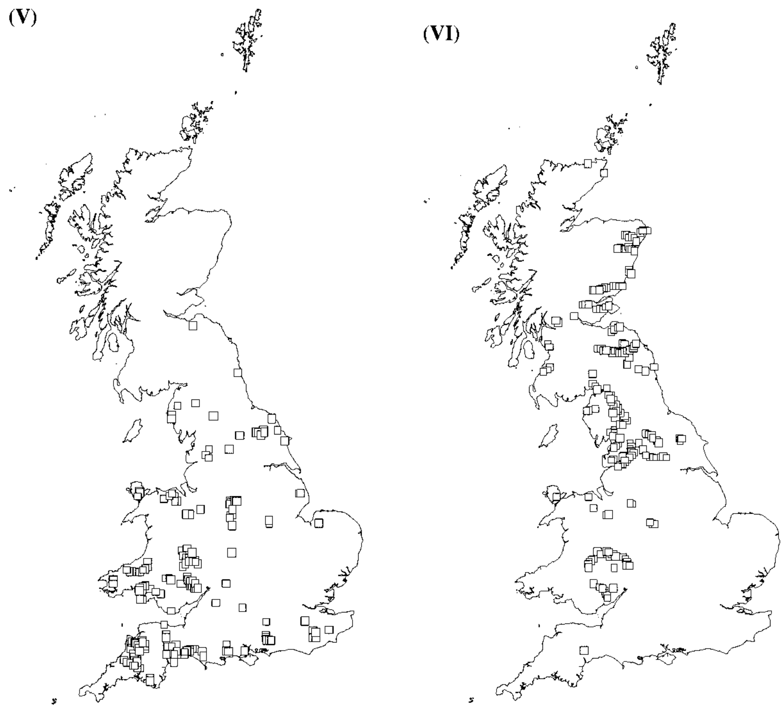


Figure 4. The location of sites in RCTs V and VI (Group B).

*Glyceria maxima*). There are no bryophytes among the most commonly occurring species in Group A, the only common non-vascular plants being the algae *Vaucheria* spp. and *Cladophora glomerata* agg.

In Group B there are only four taxa (*Hildenbrandia rivularis*, *Oenanthe crocata*, *Amblystegium riparium* and *Brachythecium rutabulum*) that are uniquely common to this group alone. Six taxa are common ( > 60% occurrence) to both Groups B and C: *Rhynchostegium riparioides*, *Verrucaria* spp., *Amblystegium fluviatile*, *Conocephalum conicum*, *Equisetum arvense* and *Lemanea flaviatilis*. Group B communities thus frequently consist of a mixture of vascular and non-vascular plants, typically having some of the most widespread taxa of Group A present alongside those of Group C.

Group C communities have very little affinity to Group A. In contrast, Group C often contains many species associated with the mesotrophic and upland extreme of Group B and the low-gradient examples from the oligotrophic Group D. Table 3 shows that a mere six taxa are commonly found only in Group C communities: *Chiloscyphus polyanthos*, *Fontinalis squamosa*, *Hygrohypnum ochraceum*, *Brachythecium rivulare*, *Schistidium alpicola* and *Angelica sylvestris* (all bryophytes except for the last). Species such as *Pellia epiphylla* and *Ranunculus flammula* are typically found in both Groups C and D but more rarely elsewhere.

Group D contains 15 taxa which are uniquely common to this group alone, dominated by bryophytes (e.g. *Racomitrium aciculare*) and oligotrophic moorland-edge species (e.g. *Nardia compressa*). The commonest fully aquatic vascular plant is the oligotrophic indicator *Juncus bulbosus*. Acidophilic and oligotrophic taxa typify Group D communities, with species such as *Polytrichum commune*, and *Carex nigra* occurring 10 times more frequently in Group D than in Group C.

## Descriptions of RCTs I–X

Tables 4 and 5 list the characteristic plant taxa and physical features associated with each of the 10 RCTs.

 

*RCT I (Group A): Lowland, low gradient rivers (three sub-types)*

Rivers with RCT I communities are usually located in south-east England and East Anglia. RCT I sites have the lowest mean altitude and shallowest gradient of all the 10 RCTs, and frequently occur in deep, wide, slow-flowing rivers. The underlying geology is predominantly clay and chalk giving rise to silty substrates. Vascular plants dominate the communities, with *Cladophora glomerata* agg. and *Vaucheria* spp. the only non-vascular plants commonly present. *Carex riparia*, *Sparganium emersum*, *Potamogeton pectinatus* and *Sagittaria sagittifolia* are more common in this RCT than in any other.

*RCT II (Group A): Lowland, clay-dominated rivers (three sub-types)*

The geographical spread of sites in RCT II is much greater than in RCT I—the lowlands of the Cheshire Plain being the most significant outlier away from central and south-east England. Sites vary greatly in terms of width, depth, and flow types but gradients are generally shallow and site altitude is invariably below 40 m. Clay is the dominant geology (and more typically a substrate than in any other RCT), but in contrast to RCT I, soft sands, oolites and other soft limestone are common and chalk is absent. Plant assemblages are similar to RCT I, but a greater taxon richness leads to a lower frequency of occurrence for any given taxon. Less common species such as *Potamogeton natans* and *Juncus acutiflorus* occur more frequently than in RCT I and vascular plants and algae dominate.

*RCT III (Group A): Chalk rivers and other base-rich rivers with stable flows (two sub-types)*

The most characteristic examples of RCT III sites occur in the rivers flowing over the chalk in southern England, headwater streams of East Anglia and east Yorkshire, and those on the oolite of the Cotswolds. The principal feature common to the great majority of sites is a stable flow regime resulting from a

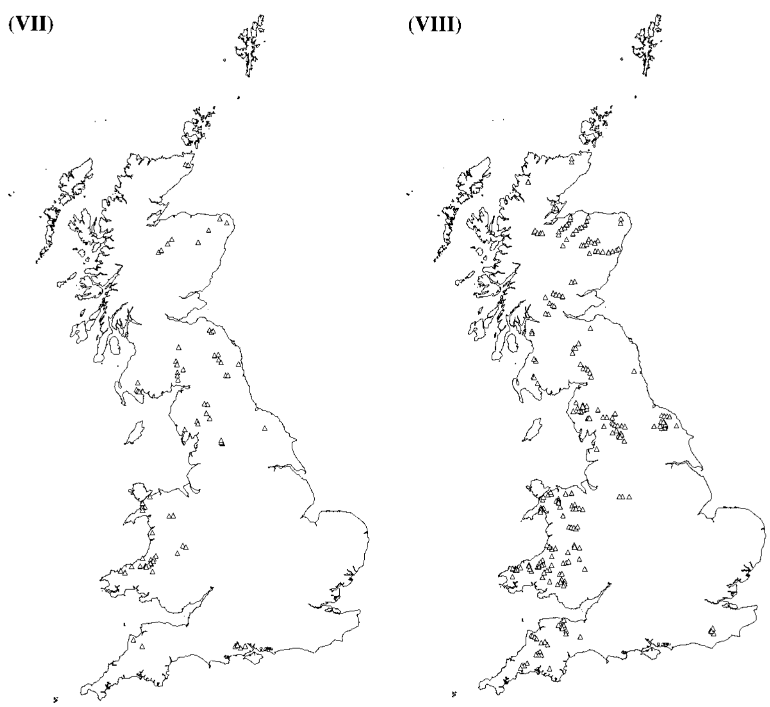


Figure 5. The location of sites in RCTs VII and VIII (Group C).


Figure 6. The location of sites in RCTs IX and X (Group D).

substantial baseflow. Underlying geology is exclusively base-rich, with chalk comprising more than 60%—more than twice that found in RCT I. Gravel substrates are more prevalent in this RCT than in any other RCT in Group A. Whilst the plant assemblages have many of the taxa typically found in RCTs I and II, *Carex acutiformis*, *Callitriche obtusangula*, *Ranunculus penicillatus* subsp. *pseudofluitans*, *Berula erecta* and *Fontinalis antipyretica* are particularly characteristic. Taxa especially associated with RCT III include *Hippurus vulgaris*, *Carex paniculata*, *Groenlandia densa*, *Phragmites australis* and *Rumex hydrolapathum*.

*RCT IV (Group A): Impoverished lowland rivers (three sub-types)*

Sites in RCT IV are widely distributed in the lowland areas of Britain but with a higher proportion found in second-order, narrow streams flowing over a range of soft geology. The overriding character of most sites is a degraded physical structure through land drainage and flood defence activities. Others suffer from depleted flows or pollution problems. Because of these key factors, mean taxon richness per site is less than 75% of other RCTs in Group A. The most typical taxa are all emergent or marginal, none of the common submerged aquatics of the other Group A RCTs occurring in more than 35% of sites.

*RCT V (Group B): Sandstone, mudstone and hard limestone rivers of England and Wales (five sub-types)*

Few sites in RCT V occur on rivers north of the River Mersey, with the exception of the Usk and the Teme. Rivers with RCT V communities tend to rise at lower altitudes than RCT VI, but have steeper gradients. As in RCT VI, there is a prevalence of sandstone and hard limestone geology but the latter is much more important, and the former much less so. Calcareous shales are also more likely to be encountered in this RCT than in others. Substrates are dominated by pebbles and cobbles and with less

Table 4. Physical characteristics of sites in River Community Types (RCTs) I–X. Results relate to combined information for all sites assigned to each of the 10 RCTs

| River Community Types | I | II | III | IV | V | VI | VII | VIII | IX | X |
|---|---|---|---|---|---|---|---|---|---|---|
| Geology (% occurrence at sites) | | | | | | | | | | |
| Calcareous clay | 36 | 34 | 12 | 29 | | | | | | |
| Non-calcareous clay | 22 | 14 | | 12 | | | | | | |
| Chalk | 31 | | 62 | 10 | | | | | | |
| Other soft limestone | | 16 | 10 | | | | | | | |
| Hard limestone | | | | | 12 | 22 | 25 | 10 | 11 | |
| Soft sand | | 18 | | 18 | 19 | 28 | | | | |
| Hard sandstone | | | | | 34 | 11 | 20 | 16 | 16 | 16 |
| Calcareous shale | | | | | 11 | | | | | |
| Non-calcareous shale | | | | | | | 17 | 34 | | 13 |
| Hard rock | | | | | | | | | 43 | 29 |
| Height at source (m) | | | | | | | | | | |
| Mean | 108 | 158 | 111 | 158 | 303 | 447 | 373 | 496 | 306 | 496 |
| Min | 25 | 25 | 25 | 10 | 30 | 61 | 20 | 100 | 10 | 100 |
| Max | 229 | 640 | 229 | 700 | 655 | 761 | 810 | 1210 | 950 | 1210 |
| Altitude of Site (m) | | | | | | | | | | |
| Mean | 38 | 47 | 54 | 58 | 75 | 72 | 125 | 125 | 76 | 193 |
| Min | 0 | 10 | 15 | 5 | 5 | 5 | 0 | 10 | 0 | 5 |
| Max | 200 | 200 | 168 | 213 | 244 | 250 | 572 | 425 | 725 | 750 |
| Slope (km per 15m fall) | | | | | | | | | | |
| Mean | 20 | 19 | 11 | 9.8 | 6.6 | 10.5 | 6.1 | 4.5 | 4.7 | 1.9 |
| Min | 2.3 | 4.2 | 2 | 0.25 | 0.1 | 0.9 | 0.5 | 0.2 | 0.1 | 0.1 |
| Max | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| Substrates (% occurrence at sites) | | | | | | | | | | |
| Silt | 54 | 39 | 48 | 39 | 11 | 11 | 26 | 2 | 39 | 2 |
| Sand | 14 | 20 | 23 | 21 | 7 | 15 | 20 | 4 | 23 | 2 |
| Clay | 49 | 57 | 18 | 28 | 9 | 4 | 5 | 0.4 | 6 | 0.4 |
| Gravel | 44 | 42 | 80 | 52 | 31 | 24 | 40 | 16 | 26 | 17 |
| Pebble | 20 | 14 | 14 | 19 | 48 | 47 | 46 | 40 | 34 | 37 |
| Cobble | 3 | 5 | 4 | 4.2 | 48 | 57 | 49 | 67 | 36 | 70 |
| Boulder | 0 | 0 | 0 | 1.7 | 22 | 31 | 22 | 52 | 31 | 65 |
| Bedrock | 0 | 0 | 0 | 0.8 | 8 | 10 | 12 | 21 | 17 | 39 |
| Flow types (% occurrence at sites) | | | | | | | | | | |
| Pool | 3 | 8 | 4 | 4 | 10 | 8 | 8 | 5 | 27 | 8 |
| Slack | 94 | 93 | 90 | 77 | 86 | 83 | 57 | 70 | 62 | 40 |
| Riffle | 1 | 5 | 2 | 12 | 14 | 7 | 30 | 9 | 43 | 41 |
| Run | 29 | 32 | 56 | 49 | 65 | 71 | 59 | 74 | 40 | 53 |
| Rapid | 1 | 0 | 1 | 2 | 8 | 9 | 9 | 43 | 26 | 58 |
| Width (m) (% occurrence at sites) | | | | | | | | | | |
| $<5$ | 7 | 24 | 27 | 71 | 36 | 13 | 41 | 24 | 50 | 50 |
| 5–10 | 13 | 51 | 46 | 33 | 37 | 23 | 38 | 43 | 34 | 43 |
| $>10$–20 | 56 | 42 | 39 | 8 | 37 | 38 | 26 | 40 | 31 | 28 |
| $>20$ | 37 | 11 | 12 | 5 | 17 | 47 | 18 | 26 | 20 | 15 |
| Depth (m) (% occurrence at sites) | | | | | | | | | | |
| $<0.25$ | 12 | 35 | 68 | 67 | 80 | 69 | 67 | 84 | 59 | 79 |
| 0.25–0.5 | 35 | 49 | 67 | 47 | 54 | 50 | 37 | 44 | 54 | 50 |
| $>0.5$–1 | 41 | 34 | 21 | 19 | 10 | 6 | 20 | 6 | 36 | 19 |
| $>1$ | 55 | 36 | 17 | 13 | 8 | 22 | 21 | 8 | 23 | 6 |

 

Table 5. Percentage frequency occurrence of the 30 most common taxa present within the sites assigned to each of the 10 River Community Types

| Species name | River Community Type | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Group A | | | | Group B | | Group C | | Group D | |
| | I | II | III | IV | V | VI | VII | VIII | IX | X |
| *Symphytum officinale* | 70 | | | | | | | | | |
| *Potamogeton pectinatus* | 85 | 68 | | | | | | | | |
| *Sagittaria sagittifolia* | 79 | 59 | | | | | | | | |
| *Nuphar lutea* | 75 | 70 | | | | | | | | |
| *Scirpus* (*Schoenoplectus*) *lacustris* | 69 | 60 | | | | | | | | |
| *Glyceria maxima* | 90 | 66 | 78 | | | | | | | |
| *Carex riparia* | 88 | | 64 | | | | | | | |
| *Lycopus europaeus* | 77 | | 62 | | | | | | | |
| *Iris pseudacorus* | 75 | | 79 | | | | | | | |
| *Sparganium emersum* | 91 | 69 | | 32 | | | | | | |
| *Apium nodiflorum* | 91 | 59 | 89 | 66 | | | | | | |
| *Scrophularia auriculata* | 70 | 68 | 82 | 70 | | | | | | |
| *Juncus inflexus* | 69 | | 74 | 50 | | | | | | |
| *Eupatorium cannibinum* | 75 | | 72 | 34 | | | | | | |
| *Enteromorpha* spp. | | 67 | | | | | | | | |
| *Rorippa amphibia* | | 58 | | | | | | | | |
| *Lythrum salicaria* | | 56 | 67 | 35 | | | | | | |
| *Alisma plantago-aquatica* | | 52 | | 30 | | | | | | |
| *Carex acutiformis* | | | 89 | | | | | | | |
| *Callitriche obtusangula* | | | 87 | | | | | | | |
| *Ranunculus penicillatus* subsp. *pseudofluitans* | | | 86 | | | | | | | |
| *Veronica anagallis-aquatica* | | | 82 | | | | | | | |
| *Berula erecta* | | | 73 | | | | | | | |
| *Elodea canadensis* | 73 | 62 | | | | 64 | | | | |
| *Lemna minor* | 72 | 66 | | 31 | | | | | | |
| *Callitriche stagnalis* | 72 | 57 | 70 | 51 | | | 54 | | | |
| *Solanum dulcamara* | 93 | 82 | 90 | 76 | 74 | | | | | |
| *Vaucheria sessilis* agg. | 73 | 74 | 74 | 50 | 73 | 51 | | | | |
| *Cladophora glomerata* agg. | 74 | 80 | 61 | 55 | 71 | 83 | | | | |
| *Epilobium hirsutum* | 91 | 90 | 100 | 87 | 64 | 66 | | | | |
| *Sparganium erectum* | 95 | 92 | 96 | 82 | 71 | 83 | 47 | | | |
| *Veronica beccabunga* | 90 | 74 | 88 | 79 | 57 | 69 | 47 | | | |
| *Nasturtium officinale* | 89 | 71 | 88 | 71 | | | 38 | | | |
| *Phalaris arundinacea* | 100 | 98 | 98 | 92 | 89 | 99 | 80 | 71 | | |
| *Mentha aquatica* | 94 | 74 | 99 | 72 | 77 | 91 | 66 | 69 | | |
| *Myosotis scorpioides* | 96 | 92 | 97 | 90 | 62 | 93 | 70 | 57 | 44 | |
| *Agrostis stolonifera* | 97 | 97 | 91 | 98 | 98 | 99 | 93 | 96 | 64 | 58 |
| *Salix* spp. | 83 | 87 | 88 | 76 | 88 | 84 | 78 | 86 | 58 | 62 |
| Other trees | 75 | 76 | 83 | 77 | 97 | 81 | 68 | 88 | 46 | 56 |
| *Polygonum amphibium* | | 68 | | 32 | | 55 | | | | |
| *Filipendula ulmaria* | | 54 | 88 | 68 | 67 | 69 | 71 | 66 | 56 | |
| *Juncus acutiflorus* | | | | | 63 | 72 | 58 | 79 | 47 | 64 |
| *Fontinalis antipyretica* | | | 67 | | 84 | 90 | 66 | 85 | 48 | 45 |
| *Juncus effusus* | | | | 62 | 49 | 60 | 82 | 68 | 88 | 81 |
| *Glyceria fluitans* | | | | 48 | 58 | 55 | 79 | 64 | 78 | |
| *Amblystegium riparium* | | | | 45 | 65 | | | | | |
| Filamentous green algae | | | | 44 | | 63 | 58 | 81 | 58 | 77 |
| *Angelica sylvestris* | | | | 41 | | | 61 | | 54 | |

 

Table 5. Continued

| Species name | River Community Type | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Group A | | | | Group B | | Group C | | Group D | |
| | I | II | III | IV | V | VI | VII | VIII | IX | X |
| *Equisetum arvense* | | | | 31 | 47 | 69 | | 54 | | |
| *Rhynchostegium riparioides* | | | | | 92 | 87 | 57 | 94 | | |
| *Oenanthe crocata* | | | | | 74 | | | | | |
| *Pellia endiviifolia* | | | | | 60 | | | | | |
| *Lunularia cruciata* | | | | | 55 | | | | | |
| *Brachythecium rutabulum* | | | | | 46 | | | | | |
| *Hildenbrandia rivularis* | | | | | 49 | 63 | | | | |
| *Lemanea fluviatilis* | | | | | 45 | 50 | | 69 | | |
| *Verrucaria* spp. | | | | | 77 | 82 | | 84 | | |
| *Conocephalum conicum* | | | | | 74 | 54 | | 65 | | |
| *Amblystegium fluviatile* | | | | | 61 | 69 | | 64 | | |
| *Chiloscyphus polyanthos* | | | | | 53 | | | 80 | | |
| *Mimulus guttatus* | | | | | | 73 | | | | |
| *Rorippa sylvestris* | | | | | | 52 | | | | |
| *Cinclidotus fontinaloides* | | | | | | 52 | | | | |
| *Caltha palustris* | | | | | | 66 | 71 | 64 | 70 | |
| *Deschampsia cespitosa* | | | | | | | 57 | 49 | 46 | 53 |
| *Ranunculus flammula* | | | | | | | 53 | 59 | 84 | 69 |
| *Pellia epiphylla* | | | | | | | 45 | 74 | 69 | 87 |
| *Stachys palustris* | | | | | | | 43 | | | |
| *Senecio aquaticus* | | | | | | | 38 | | | |
| *Callitriche hamulata* | | | | | | | 38 | | | |
| *Equisetum fluviatile* | | | | | | | 43 | | 63 | |
| *Galium palustre* | | | | | | | 42 | | 61 | |
| *Myriophyllum alterniflorum* | | | | | | | 41 | | 59 | |
| *Sagina procumbens* | | | | | | | 40 | | | 47 |
| Ferns | | | | | | | 37 | 60 | 54 | 58 |
| *Hygrohypnum ochraceum* | | | | | | | | 68 | | |
| *Fontinalis squamosa* | | | | | | | | 68 | | |
| *Schistidium alpicola* | | | | | | | | 59 | | |
| *Brachythecium rivulare* | | | | | | | | 58 | | |
| *Thamnobryum alopecurum* | | | | | | | | 54 | | |
| *Scapania undulata* | | | | | | | | 56 | | 71 |
| *Juncus bulbosus* | | | | | | | | | 84 | 75 |
| *Carex nigra* | | | | | | | | | 76 | 54 |
| *Eleocharis palustris* | | | | | | | | | 58 | |
| *Juncus articulatus* | | | | | | | | | 57 | |
| *Carex rostrata* | | | | | | | | | 53 | |
| *Potamogeton polygonifolius* | | | | | | | | | 48 | |
| *Potamogeton natans* | | | | | | | | | 48 | |
| *Viola palustris* | | | | | | | | | 58 | 57 |
| *Molinea caerulea* | | | | | | | | | 50 | 56 |
| *Sphagnum* spp. | | | | | | | | | 50 | 63 |
| *Anthroxanthum oderatum* | | | | | | | | | 49 | 79 |
| *Racomitrium aciculare* | | | | | | | | | | 83 |
| *Potentilla erecta* | | | | | | | | | | 66 |
| *Polytrichum commune* | | | | | | | | | | 65 |
| *Nardus stricta* | | | | | | | | | | 61 |
| *Hyocomium armoricum* | | | | | | | | | | 47 |

Table 5. Continued

| Species name | River Community Type | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Group A | | | | Group B | | Group C | | Group D | |
| | I | II | III | IV | V | VI | VII | VIII | IX | X |
| *Bryum pseudotriquetrum* | | | | | | | | | | 47 |
| *Carex demissa* | | | | | | | | | | 46 |
| *Brachythecium plumosum* | | | | | | | | | | 45 |
| *Marsupella emarginata* | | | | | | | | | | 45 |
| *Achillea ptarmica* | | | | | | | | | | 41 |
| *Jungermania atrovirens* agg. | | | | | | | | | | 40 |
| % Occurrence of 30th most common taxon | 69 | 52 | 61 | 30 | 45 | 50 | 37 | 49 | 44 | 40 |
| No. of aquatic vascular plant spp. (out of 30) | 11 | 12 | 8 | 6 | 1 | 2 | 5 | 0 | 4 | 1 |
| No. of aquatic bryophyte spp. (out of 30) | 0 | 0 | 1 | 3 | 4 | 5 | 3 | 12 | 3 | 10 |
| Mean taxon richness per site (whole dataset) | 46 | 38 | 42 | 29 | 35 | 40 | 31 | 39 | 31 | 31 |

fine material so characteristic of RCTs I–IV. In marked contrast to RCTs I–IV none of the submerged aquatic taxa occurs in more than half the sites and *Sparganium erectum* is the only emergent to do so. Submerged habitats are often dominated by mosses, the most important being *Rhynchostegium riparioides*, *Fontinalis antipyretica* and *Amblystegium fluviatile*. Of the taxa common to both RCTs V and VI, *Oenanthe crocata*, *Solanum dulcamara*, *Conocephalum conicum* and *Vaucheria* spp. are more frequent in RCT V.

*RCT VI (Group B): Sandstone, mudstone and hard limestone rivers of Scotland and northern England (five sub-types)*

RCT VI communities show a clear geographical distribution, invariably occurring in hard limestone and sandstone catchments north of the River Mersey. Although channel gradient is significantly steeper than in RCT V, substrate types occur in broadly similar proportions. Of the common species encountered in both RCTs V and VI, *Myosotis scorpioides*, *Mentha aquatica*, *Mimulus guttatus*, *Equisetum arvense*, *Caltha palustris*, *Elodea canadensis* and filamentous algae are much more prevalent in RCT VI.

*RCT VII (Group C): Mesotrophic rivers dominated by gravels, pebbles and cobbles (four sub-types)*

RCT VII sites are well scattered around Britain with the most typical in catchments of more basic geology than RCT VIII or with relatively stable flows. Shales, hard limestone and hard sandstone dominate the geology of RCTs VII and VIII. However, there is a far greater proportion of sites on hard limestone and a far smaller proportion on non-calcareous shales for RCT VII than RCT VIII. Typical site altitudes are similar but rivers with RCT VIII sites have much higher sources. Gradients are generally shallower in RCT VII but there is a major transition from very steep gradients in VIIa to slack gradients in VIId. Fine substrates, ranging from silts to sands and gravels are far more common in RCT VII than VIII. Plant assemblages are characterized by wetland-edge species with far fewer bryophytes than either RCT VIII or RCTs V and VI in Group B (reflecting finer sediments). Of the taxa common to both VII and VIII, *Phalaris arundinacea* and *Myosotis scorpioides* have stronger associations with VII, as do *Callitriche stagnalis*, *C. hamulata*, *Equisetum fluviatile*, *Myriophyllum alterniflorum*, *Juncus articulatus*, *Potamogeton natans* and *Nasturtium officinale*.

*RCT VIII (Group C): Oligo-mesotrophic rivers (five sub-types)*

Sites in RCT VIII are typically found downstream of highland, base- and nutrient-poor (oligotrophic) sites. Gradients are steeper in RCT VIII than in RCT VII, and coarse substrates (cobbles, boulders and bedrock) dominate. The higher proportion of rocks, and their less base-rich nature, results in a wide variety of bryophytes. Those more commonly found in RCT VIII than in RCT VII include: *Rhynchostegium riparioides*, *Chiloscyphus polyanthos*, *Pellia epiphylla*, *Hygrohypnum ochraceum*, *Amblystegium fluviatile*, *Thamnobryum alopecurum*, *Scapania undulata* and *Schistidium alpicola*.

*RCT IX (Group D): Oligotrophic, low-altitude rivers (three sub-types)*

Sites in RCT IX occur in nutrient-poor rivers. Their underlying geology is broadly similar to RCT X, but the absence of non-calcareous shales and the presence of hard limestone gives the RCT a slightly less oligotrophic nature. Site altitudes are lower, too, and gradients shallower than in RCT X giving rise to a greater abundance of silty and sandy substrates and a much lower proportion of cobbles, boulders and bedrock. The contrasting gradient and substrate characteristics are reflected by the plant assemblages which in RCT IX are dominated by oligotrophic vascular plants, such as *Juncus bulbosus*, *Equisetum fluviatile*, *Myriophyllum alterniflorum*, *Potamogeton polygonifolius*, *Carex rostrata* and *Scirpus* (*Eleogiton*) *fluitans*. The only mosses present in the top 30 common taxa are *Fontinalis antipyretica* (typically a more lowland species) and *Sphagnum* spp.

*RCT X (Group D): Ultra-oligotrophic rivers (five sub-types)*

RCT X sites are found on all rivers rising at high altitudes on base-poor rock and/or where blanket bog or acid heath dominates the catchment upstream. The oligotrophic water, steep gradients, and an abundance of cobbles, boulders, and bedrock provide the conditions for bryophytes to thrive. Common species include *Pellia epiphylla*, *Racomitrium aciculare*, *Scapania undulata*, *Hyocomium armoricum*, *Bryum pseudotriquetrum*, *Marsupella emarginata* and *Jungermania atrovirens*.

## DISCUSSION

### A comparison of the original and the revised classifications

Figure 7 compares the allocation of sites to types and sub-types to the fourth division in the original and the revised classifications. For some rivers, and for some RCTs, there has been little or no change from the original classification; for others, however, major changes have taken place which have helped increase the confidence of assigning sites to particular RCTs.

Changes in site classification can best be interpreted by reference to Group A. The new RCT I (old A1) has 59 of the previous sites in the classification re-assigned to it, with 48 from the original A1 and 11 from its nearest neighbour A2, but none from anywhere else. However, 110 sites were previously assigned to A1, and almost half (43) have now been allocated to the new RCT II, 10 to RCT III, and nine to RCT IV. By comparison, of the 59 sites previously allocated to A3, all but one have been reassigned in the new classification to the classic chalk stream RCT III, with 23 other sites now being added from elsewhere in Group A from different parts of the original classification. Reference to the new RCT VIIa/b and RCT DIXa in Figure 7 shows that these are new groupings, primarily comprising sites not included in the first survey programme, and therefore represent an extension to the variation originally described.

 

| | AI | AII | AIII | AIV | BV a-c | BV d-e | BVI a-c | BVI d-e | CVII a-b | CVII c-d | CVIII a-c | CVIII d-e | DIX a | DIX b-c | DX a-b | DX c-e |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **A1** | 48 | 43 | 10 | 9 | | | | | | | | | | | | |
| **A2** | 11 | 80 | 6 | 22 | 5 | | 4 | 2 | | | | | | | | |
| **A3** | | | 58 | 1 | | | | | | | | | | | | |
| **A4** | | | 7 | 46 | 22 | | | 3 | | | | | | | | |
| **B1** | | | | | 1 | 3 | 17 | 41 | | | | | | | | |
| **B2** | | | | | | | 30 | | | | | | | | | |
| **B3** | | | | | 30 | | 47 | 3 | | | | | | | | |
| **B4** | | | | | 47 | 23 | 22 | | | | | | | | | |
| **C1** | | | | | 2 | | 4 | 1 | | | 36 | 19 | | | | |
| **C2** | | | | | 3 | 12 | 1 | 1 | | | 65 | 9 | | | | 1 |
| **C3** | | | | | 2 | 6 | | 2 | 1 | 25 | 15 | 9 | | 4 | | 1 |
| **C4** | | | | | | 2 | | 3 | 2 | 3 | 10 | 31 | | 3 | | |
| **D1** | | | | | | | | | | | | 12 | | | 25 | |
| **D2** | | | | | | | | | | | | 4 | | | 10 | 1 |
| **D3** | | | | | | | | | | | 2 | 1 | | 1 | 11 | 36 |
| **D4** | | | | | | | | | | | | | | 3 | 14 | |

Figure 7. Re-allocation of sites in the new classification. Vertical columns show which of the 1978–82 survey sites were assigned to the 16 principal sub-types in the new classification. Horizontal columns show from which sub-groups in the previous classification they have been transferred.

RCTs I, II, III and IV have therefore remained essentially unchanged, although the new system places most fenland rivers in one RCT alone (I), with many sites previously assigned to RCT I (where a clay substrate overrides the influence of deep, slow flowing water) now being assigned to RCT II. The latter forms a well defined category to which most macrophyte communities in rivers with plentiful clay in the catchment will be assigned.

RCT III now includes sites on chalk, as well as some from other soft limestone types, such as oolite, and more headwater sites where springs from underlying chalk flow over clay and other substrates. The revised classification gives an even clearer grouping of rivers fed by base-rich groundwater.

RCT IV has remained unchanged and represents a 'dumping ground' for lowland systems with impoverished floras or lowland sites where elements of B or even C communities are well represented. Communities on physically degraded lowland headwater streams are most frequently allocated to this RCT, as are those that experience the impact of low flows caused by over-abstraction.

RCTs V and VI are even more closely correlated with sand/mudstone and hard limestone than before, and the north–south divide is even more distinct. The types are now the reverse of what they were (i.e. the old V is the new VI and vice versa). The inversion has been made to produce a classification with a logical downstream sequence to it, and where there is also a gradient in trophic status; the new RCT VI thus supports more species indicative of oligotrophic waters, and has more taxa in common with Group C. The new classification, like the old, shows a distinct geographical bias, with most of the new RCT V sites in England south of the River Mersey, and RCT VI sites north of it.

More winterbournes (groundwater-fed streams which flow only in winter) and small, lowland streams flowing on base-poor sands are included within RCT V than before. The upper reaches of several lowland and southern sites on mixed sands and clay, placed originally in the impoverished RCT IV, have moved to RCT V in the new system. These, and the winterbournes, form a distinct sub-type within RCT V (Holmes *et al*., in press).

There has been a complete re-arrangement of the old Group C. The new RCT VII can be regarded now as a more southerly and meso-oligotrophic type than VIII which is distinctly 'northern' and/or genuinely oligotrophic. The two RCTs are now more clearly defined than before, since most sites allocated to RCT VII have more aquatic vascular plants than those in RCT VIII which are dominated by bryophytes. This is well illustrated by the communities of fast-flowing rivers in Scotland and in the Pennines of England, where sites are predominantly in RCT VIII instead of VII. Conversely, sites in rivers that flow through upland bog plateaux are now in the new RCT VII.

The separation of RCT IX from RCT X is much clearer than before owing to the increased number of sites surveyed. As well as being less oligotrophic, RCT IX is more characteristic of lower altitudes and lower gradients and contains more aquatic vascular plants typical of oligotrophic waters, and far fewer bryophytes than RCT X.

## Applications

### *Nature conservation evaluation*

The statutory conservation bodies in Britain have a duty under the Wildlife and Countryside Act 1981 to designate areas considered important for conservation as Sites of Special Scientific Interest (SSSIs). This designation may be applied to areas of land or water, including rivers (Boon, 1991). The main aim of the original survey was to erect a classification of British rivers which could be used in nature conservation evaluation prior to SSSI designation. This process of assessment is now part of the guidelines for selecting SSSIs, published by the Nature Conservancy Council (then the Government's statutory nature conservation adviser) (Nature Conservancy Council, 1989).

 

The classification system allows the plant communities of any river length to be compared with others of the same RCT in terms of widely accepted conservation criteria such as species richness, community representativeness, and rarity (Ratcliffe, 1977). The classification also enables the extent of different RCTs to be determined for Britain as a whole, and within the boundaries of the three conservation agencies which replaced the NCC (English Nature, Scottish Natural Heritage, and the Countryside Council for Wales). Many of those rivers identified during the 1980s as worthy of designation have now become, or are in the process of becoming, SSSIs (especially in England).

While the SSSI guidelines encourage river evaluations to take account of a broad range of ecological interests, no standard methods have been available, until recently, for doing so. Consequently, the assessment of river conservation value has tended to focus on aquatic plants, with far less emphasis on other species groups or on the physical characteristics of river corridors. Even this limited evaluation using macrophyte communities has lacked a certain degree of rigour. In 1992, work commenced on a collaborative project (led by Scottish Natural Heritage) to broaden the scope of river conservation assessment, and to make the procedure more repeatable and less subjective. The end product has been named 'SERCON'—System for Evaluating Rivers for Conservation—and uses a wide range of biological, physical and chemical data to provide indices of conservation value according to criteria such as naturalness, physical diversity, and species richness (Boon *et al*., 1997). The botanical classification of British rivers is an integral part of SERCON, fulfilling two roles. Firstly, it enables the representativeness of macrophyte communities to be assessed for a given stretch of river, by comparing the species assemblage observed with that predicted to be characteristic for the RCT. Secondly, physical data on substrates and fluvial features associated with the 10 RCTs are used to generate a profile of each RCT. The degree to which the observed characteristics match those predicted for the RCT provides an assessment of physical representativeness.

It should be emphasized that SERCON was not designed principally with SSSI selection in mind, although it has already been applied in Northern Ireland to assist in selecting Areas of Special Scientific Interest (equivalent to SSSIs) (Susanna Allen, personal communication).

### *River management*

The macrophyte classification system has been used on numerous occasions by organizations responsible for river management, water resources and planning control. Where plant communities especially rich for their RCT are present in rivers subject to routine desilting for flood defence, the Environment Agency of England and Wales often takes care to remove only the minimum amount of silt and vegetation to ensure that the complete assemblage is retained after the work is completed. The system may also be used in both pre- and post-impact assessments for water resource projects. For example, the River Darent, a chalk stream in south-east England, has more than 70% of its recharge removed through groundwater abstraction, resulting in an extremely impoverished macrophyte community. The classification system provides a means of underpinning impact assessment and appraising the success of ameliorative measures in a more objective manner than was previously possible.

The macrophyte database has been used recently in constructing the Mean Trophic Rank (MTR) system for assessing trophic enrichment in UK rivers. This system has been developed by one of the authors (NTHH) in association with the Environment Agency to assist in monitoring more than 200 sites that fall within the scope of the EC Urban Wastewater Treatment Directive. The MTR system is similar to that used for assessing standing waters using the DOME approach of Palmer *et al*. (1992). All aquatic macrophyte species are assigned a number from 1 to 10 depending on their tolerance to, or preference for, nutrient-enriched (1) or nutrient-poor (10) water. It has been used for 3 years and the results are now being tested against water chemistry data. Early indications are that the system is a very effective tool in water quality monitoring, especially when used alongside invertebrates and other biota. Some rivers show large decreases in MTR scores downstream of discharges, most notably in oligotrophic headwaters, but where lowland rivers are already heavily enriched even a large discharge may have minimal effect on the MTR. Thus, the system provides support for concentrating conservation efforts in headwaters where even very small discharges can have a significant impact.

## CONCLUSIONS AND FUTURE DEVELOPMENT

The results have confirmed that aquatic macrophytes are a valuable tool for classifying rivers, and suggest that in the absence of natural stress or human impact (e.g. drought, abstraction) most communities are sufficiently robust to remain stable over time. The survey method has proved to be resilient, yielding predictable results from surveys carried out by a wide range of competent surveyors. The procedure has been shown to be cost-effective, as a classification into group, RCT and sub-type can be carried out on the river bank immediately after survey if required. Since the survey of a 1 km stretch of river should rarely take more than 1.75 h, a site can easily be surveyed and classified within 2 h using a dichotomous key (Holmes *et al.*, in press).

There are several ways in which the present classification system might be developed further. Perhaps the most pressing need is to extend it to Northern Ireland. Following a systematic survey of aquatic plants in the province in 1996, a preliminary classification of river sites will be made using the present system. This should be seen as an interim measure until the data can be integrated and reanalysed, thus producing a classification for the whole of the UK rather than for Britain alone.

The recent development of other systems of classifying rivers in the UK, such as the Environment Agency's River Habitat Survey (RHS) (Raven *et al.*, 1997) creates an opportunity for a range of cross-comparisons. For example, in RHS physical habitat features at sites along the length of a river may be predicted from variables such as altitude and slope. In SERCON, rivers are divided into lengths termed 'Evaluated Catchment Sections' (ECSs), principally on the basis of their physical features (Boon *et al.*, 1996). In terms of plant communities, rivers can be sub-divided into 'zones' each zone synonymous with a 'Group' (A–D)—with most British rivers having two zones, some having three and a very few having all four from D at the source through to A in their lowermost reaches. By examining the geographical and geomorphological features underlying physical classification systems, and comparing them with the subdivisions resulting from botanical classification, it should be possible to re-examine the concept of river zonation and downstream change in biotic and physical features.

The recent surge of interest in using macrophytes as indicators of water quality may lead to the development of a system for predicting macrophyte assemblages at riverine sites on the basis of environmental variables. This would be a direct parallel to RIVPACS (River Invertebrate Prediction and Classification System; Wright *et al.*, 1989), and would add to the suite of methods available at present for river monitoring. The significance of these developments extends beyond the UK, as other countries in the European Community are also investigating the use of river macrophytes as indicators of environmental quality. Through bodies such as CEN (European Committee for Standardization) they are actively working towards common standards for river classification, evaluation and monitoring using organisms such as macrophytes, diatoms and invertebrates—an important initiative given the requirements of the EC Habitats Directive and the forthcoming Water Framework Directive.


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