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The aquatic macrophytes of an English lowland river system: assessing response to nutrient enrichment

Benoît O. L. Demars & David M. Harper
Ecology Unit, Department of Biology, University of Leicester, Leicester LE1 7RH, U.K.

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Abstract

Assessment of the effects of nutrients in running water upon macrophytes is compounded by the variety of additional environmental factors which influence their growth. Some classification schemes have been effective in detecting eutrophication on a national or regional scale, and also downstream changes in large single catchments. However, in lowland rivers with naturally nutrient-rich geologies, detection of change at smaller spatial scales has been difficult. This study examined the macrophyte community at 44 sites on the river Welland, a small lowland catchment rising below 150 m in Leicestershire, England. The community at 23 of these sites was adequate for further analysis. The data show that the clearest effect on community composition is caused by watercourse size. However, sites below sewage works, even small village works, did show a reduction in Mean Trophic Rank, (MTR – an assesment system introduced into the UK over the last three years using a 10–100 scale based upon scores and cover value of indicator species). Overall there was a slight but significant correlation of MTR with soluble phosphate and nitrate. The effectiveness of the MTR method is limited at full catchment scale by low numbers of the indicator taxa at small upstream sites. Catchment-scale assessment of the plant community is probably best served by more detailed phytosociological analysis and by the further development of the 'habitat templet' approach.

Introduction

It is well known that excessive plant growth in aquatic systems is largely caused by the supply of nutrients, especially nitrate and phosphate, (Hutchinson, 1970; Trémolières et al., 1991; Peltre et al., 1993) The phenomenon is better understood in lakes, both as a slow natural process and one which has increased rapidly due to human activity during the late 19th and the 20th centuries (Lachavanne, 1982). In such waters, the major manifestations are development of algal blooms with an accumulation of organic matter and a decrease of oxygen leading to increased cost of water treatment and reduction in aesthetic and fishery value and in fish catches (Harper, 1992). The manifestations have been less well researched in lotic waters, but primarily involve increases in biomass and decreases in diversity of aquatic macrophytes, chiefly angiosperms (Vander Borght et al., 1982; Muller, 1990; Haury & Muller, 1991; Grasmück et al., 1993; Mesters, 1995; Thièbaut & Muller, 1995).

Although there have been numerous studies of the aquatic plant communities of running waters, few of them have been able to clearly identify the effects of nutrients at single catchment scale because of the synergistic effects of other environmental factors (Frontier & Pichod-Viale, 1995). The major ones are current velocity (e.g. Fenessy et al., 1994), substrata (e.g. Peltier & Welch, 1969; Haslam, 1978), discharge variation (e.g. Sheldon, 1986), light (e.g. Westlake, 1965; Edwards, 1969), overall water quality (e.g. Robach et al., 1991), as well as nutrients. Biotic factors known to be of importance are competition (e.g. den Hartog, 1982; Sand-Jensen, 1990) and physical or grazing effects of animals (e.g. Eichenberger & Weilenmann, 1982; Underwood, 1991).

Even trying to understand the direct effect of nutrients is compounded by the fact that, depending upon species, the nutrients are absorbed either by roots or by stems and/or leaves, or by all together in varying proportions depending on the level of nutrients in both interstitial water and external water (Denny, 1972; DeMarte & Hartman, 1974; Twilley et al., 1977; Carignan & Kalff, 1980; Moore et al., 1994).

Nitrogen also has important sediment-water relationships, although these are less directly dependent upon plants, and more on the microbial processes such as denitrification and ammonification (Owens et al., 1972). The ratio of N/P for optimum growth varies from 7.15 (Vander Borght et al., 1982) to about 10 according to species (Mainstone et al., 1994). Both phosphorus, and particularly nitrogen, are influenced by the structure of the riparian ecotone (Segal, 1982; Kolasa & Zalewski, 1995).

Perhaps because of the complexities of their environmental relationships, much study of macrophytes in flowing waters has been community-based (Jones, 1955; Whitton & Buckmaster, 1970; Holmes & Whitton, 1975a, 1975b; Ham et al., 1981; Eichenberger & Weilenmann, 1982; Holmes, 1987; Birch et al., 1989), especially following perturbation by human activities. The main perturbations studied have been canalization (Lubke et al., 1984; Brookes, 1986), inter-basin water transfer (Holmes & Whitton, 1975a, 1977a, 1977b), hydroelectricity generation (Holmes & Whitton, 1981; Ortscheit et al., 1982; Ortscheit, 1985) and water quality changes (Haslam, 1987, 1990). Succession (Dawson et al., 1978; Wright et al., 1981; Segal, 1982) and community changes as a consequence of species' ecophysiological responses (Grime, 1977; Lubke et al., 1984) are important components of the plant community response to perturbations.

There have been six approaches to assessment of the quality of the aquatic ecosystem through macrophyte communities. These are:

1. Identification of community assemblages (Seddon, 1972; Haslam & Wolseley, 1981; Muller, 1990; Palmer et al., 1992; Grasmück et al., 1995) in waters of different type.
2. Biomass measurements (Edwards & Owens, 1960; Westlake, 1982; Rodgers et al., 1983; Madsen & Adams, 1989; Haury & Gouesse Aidara, 1990; Peltre et al., 1995).
3. Classification based upon geology-geomorphology-drainage order combination (Haslam, 1978) for natural vegetation leading to estimate of damage rating for human impacts (Haslam, 1982).
4. Ecomorphology (den Hartog, 1982; de Lange & van Zon, 1983; den Hartog & van der Velde, 1988),
5. Classical phytosociology (de Lange, 1972; Felzine, 1977, 1979, 1981, 1982; Jensen, 1979; Wiegleb, 1980, 1981b, 1983, 1984; Hamel & Béhreur, 1982; Klein & Carbiener, 1988; Carbiener et al., 1990; Toivonen & Huttunen, 1995; Rodwell et al., 1995).
6. Identification of communities using weightings to indicator species (Harding, 1981; Holmes, 1983; Holmes & Newbold, 1984; Newbold & Holmes, 1987; Holmes, 1994, 1995, 1996; Haury et al., 1996).

Some of these methods have been tested in continental Europe (Haury, 1982, 1989, 1991, 1992; Haury & Dutartre, 1990; Léglize et al., 1991; Haury & Peltre, 1993) but not widely compared.

At present the method increasingly used in the United Kingdom is an indicator species-based method, known as 'Mean Trophic Ranking' (MTR), developed by Holmes (1994, 1995, 1996) for the Environment Agency (Kelly & Whitton, 1994). It is succesfully used for quantifying the advance of eutrophication caused by rising nutrient concentrations and also its regression caused by nutrient control, principally at sewage treatment works. However, it has rarely been independently tested and in addition three important questions currently remain unresolved, (Holmes, 1995): these are:

1. Whether the Mean Trophic Rank (MTR) can give usable results in a catchment naturally (geologically) rich in nutrients?
2. To what lower limits of watercourse size the method is suitable?
3. How it compares with modern, developments of the phytosociological methodology?

The present study examined a single catchment in lowland England, on mixed clay/limestone geology, in order to answer these questions and to provide an independent assessment of the method.

Methods

Study area

This study catchment was located in the East Midlands of England (Figure 1). The river Welland, rising just below 150 m a.s.l., drains a catchment area where the clay geological nature leads to a mesotrophic

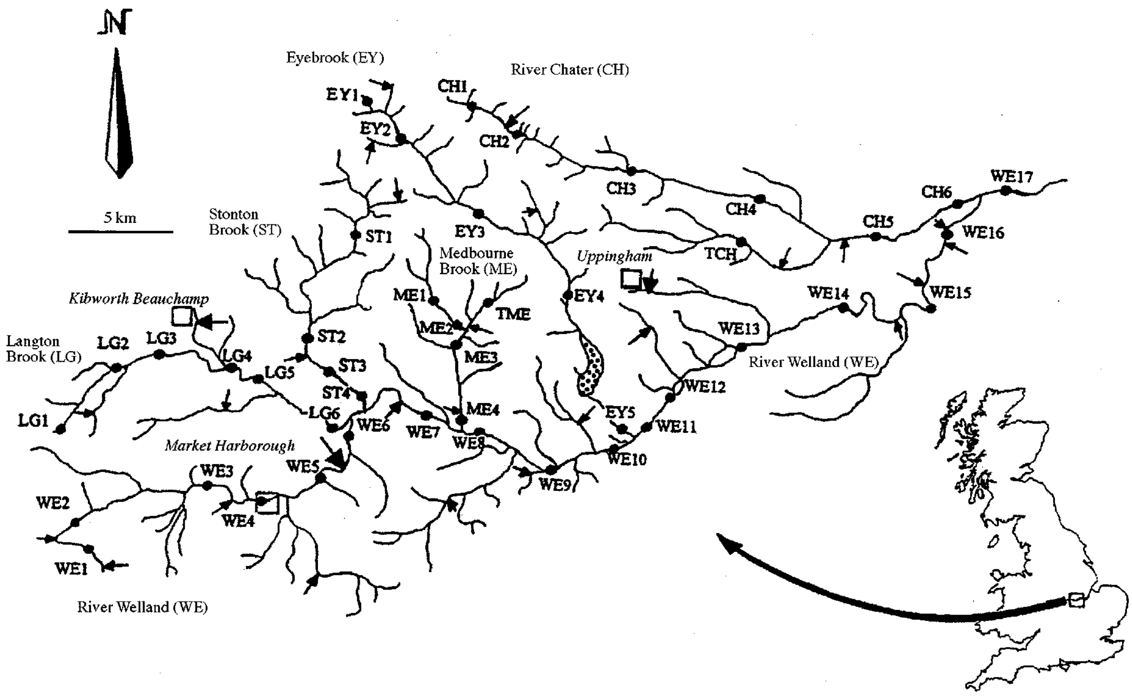

Figure 1. The river Welland catchment area, Eastern England. • site; → rural sewage works; → urban sewage works; ☐ town.

aquatic environment (Haslam, 1978). Near its sources, streams flow through small pasture-dominated hills. In the lower reaches of the tributaries and the main Welland valley, the relief becomes flatter with cultivated fields and a broad floodplain. Throughout the catchment are villages many with small sewage treatment works, and a few towns, two of which have major urban sewage treatment works (Kibworth Beauchamp, 5 000 people and Market Harborough, 20 000). The distribution of sampling sites covered all the catchment area as far as the town of Stamford, below which the river enters the East Anglian 'fens' and is heavily canalised and embanked as it flows above land level.

Field sampling and analysis

The study was carried during June and July when the flora was sufficiently developed. Five hundred metre sections of river were surveyed and all aquatic species, in-stream and riparian, were identified. Keys used were Watson, 1968; Haslam et al., 1975; Smith, 1978; Montegut, 1987; Cook, 1990; Preston, 1995a. Species names follow Stace (1991). A sketch map was drawn for each 100 metre stretch at the site.

Calculation of MTR was carried out from all the bioindicator taxa (Holmes, 1996) for each site as follows:

$$\mathrm{MTR} = \frac{\Sigma(\mathrm{STR} \times \mathrm{SCV})}{\Sigma\mathrm{SCV}} \times 10$$

The STR (Species Trophic Rank) was assigned from Holmes (1996). It ranges from 1 (a species associated with an eutrophic environment) to 10 (species associated with an oligotrophic environment). SCV (Species Cover Value) class scale C for 100 metres survey length was used (Standing Committee of Analysts, 1987). The calculated MTR falls between 10 and 100.

The results had to be interpreted with caution when fewer than 10 bioindicator taxa were recorded. A minimum of 5 was probably required (Holmes, 1995). A measure of confidence of typicality, and records of the main physical characteristics (width, depth, substrata, current, shading, water clarity, bed stability) were also made at each site. These were grouped in classes for subsequent analysis. If the measure of confidence of typicality was poor and the number of bioindicator taxa low, the sites were not used in the analysis. Out of 44 sites surveyed, only 23 were suitable for their adequate measure of confidence of typicality but also because of the availability of chemical analysis.

Chemical analysis of soluble phosphate and nitrate were available for 33 sites from the Environment Agency, Anglian Region and expressed as a mean during the macrophyte growing season. The data were grouped in classes (Meddis, 1984); raw data and data classes were strongly correlated and highly significant (Student test or R table (Sokal & Rohlf, 1995)). indicating that the data classes were valid.

The limits of the method were demonstrated by a regression analysis (Logarithmic-X model was the most appropriate) of the number of bioindicator taxa with distance from the source performed with 'Statgraphic'. MTR-nutrient correlations (linear models were the most appropriate) were also performed with 'Statgraphic'.

A hierarchical classification of the sites and taxa were performed with TWINSPAN (Two Way Indicator Species Analysis) to group the sites and the taxa according to the physico-chemical factors and the species abundance-dominance coefficient of Braun-Blanquet (1 +; 2 $<$ 5%; 3 5–25%; 4 25–50%; 5 50–75%; 6 $>$ 75%). The nine point scale was not used to avoid weighting intermediate pseudospecies without any ecological reason. Data ordinations were performed with the program DECORANA using Detrended Correspondance Analysis (DCA). These two programs (Hill, 1994) were used in the software VESPAN III (Malloch, 1995).

TWINSPAN and DCA were re-run without chemical data to provide objective groups of species. Only the species present in more than three sites were used. Cover coefficients were calculated to show the relative importance of the species within and between the groups by taking into consideration both frequency and abundance (as defined by Rodwell et al., 1995) of the species.

Results

Indicator value of the MTR

The number of bioindicator taxa in the upper water courses was small: often around or below five and nearly always below 10 (Figure 2). Nevertheless, the MTR at upper sites above sewage works (or with only very small ones) was generally above 35 (e.g. Medbourne and Eye Brook: Table 1) with drops of $>$ 20% below treatment works. The main river Welland is affected from its source to the confluence with the Chater by a succession of small sewage works and tributaries and so its MTR never exceeded 30.

MTR was significantly but weakly correlated with soluble nitrate ($r = -0.43$; $P < 0.042$) and phosphate ($r = -0.58$; $P < 0.003$).

This reduction in the MTR below sewage works and the MTR-nutrients correlation demonstrates that this method can detect changes in small, lowland watercourses, although the weakness of the correlation indicates a need to further refine the method.

The macrophyte community in most of the upper sites is poor in bioindicator taxa and very rich in amphibious and hygrophilic species which are found around the bank. Ideal conditions for their growth are created by cattle poaching. Collapsed banks allow species such as *Scrophularia auriculata*, *Cirsium palustre*, *Rumex* sp., *Juncus effusus*, *Juncus inflexus*, *Ranunculus repens* and even *Urtica dioica* to grow.

In the upstream tributaries shading alternates with open stretches in pastures; and short riffles contrast with pools and small woody debris dams. This gives enormous physical variation over a survey length which masks any chemical effects. It is thus difficult to establish the MTR in the upper streams with confidence. It performs better when the score uses more bioindicator taxa with strong Species Cover Values.

Plant community

The species recorded are shown in Table 2, together with their abundance-dominance coefficient. The two first divisions of the TWINSPAN hierarchical classification showed a clear contrast between the taxa found in small streams and those found in only the lower course of the River Welland. The DCA (Figure 3) indicated the basis for the differences: axis 1 clearly represented the watercourse size: group I the uppermost sites, group II lower tributary and intermediate sites on the main River Welland, groups III & IV only the lower course of the River Welland. These analyses also revealed a heterogeneity within the TWINSPAN groups, caused by species with different Species Trophic Rank grouping together, and species characteristic of different physical environments doing likewise. For instance, *Potamogeton pectinatus* and *Enteromorpha sp.*, indicators of high eutrophication, were associated with *Potamogeton perfoliatus*, *Ranunculus penicillatus*, and *Lemna minor*, species characteristic of a mesotrophic environment. *Ranunculus penicillatus*, characteristic of running water, was close to *Lemna* and *Nuphar lutea*, characteristic of lentic conditions. There was also contrast in the number of bioindicator taxa: fewer than 50% for group I

Table 1. List of the 44 sites with their MTR and codes used for the species list in Table 2. Those 23 sites selected are in bold

Sites	MTR	Codes	Sites	MTR	Codes	Sites	MTR	Codes
WE1	–	10	LG1	36,6	22	EY1	36,7	34
WE2	25,0	11	LG2	34,0	23	EY2	43,7	35
WE3	26,7	12	LG3	34,3	18	EY3	37,5	36
WE4	30,0	1	LG4	25,4	19	EY4	25,9	33
WE5	24,8	2	LG5	27,3	20	EY5	28,3	37
WE6	23,6	3	LG6	30,5	21			
WE7	28,4	4				CH1	33,3	39
WE8	28,8	13	ST1	24,0	24	CH2	30,0	40
WE9	24,6	14	ST2	30,6	25	CH3	28,6	41
WE10	21,6	5	ST3	29,0	26	CH4	26,0	43
WE11	24,6	6	ST4	36,4	27	TCH	18,9	42
WE12	26,0	15				CH5	27,4	38
WE13	26,8	16	ME1	40,0	28	CH6	37,6	44
WE14	23,2	7	ME2	38,7	29			
WE15	26,3	17	TME	36,8	30			
WE16	25,2	8	ME3	34,2	31			
WE17	25,3	9	ME4	26,7	32			

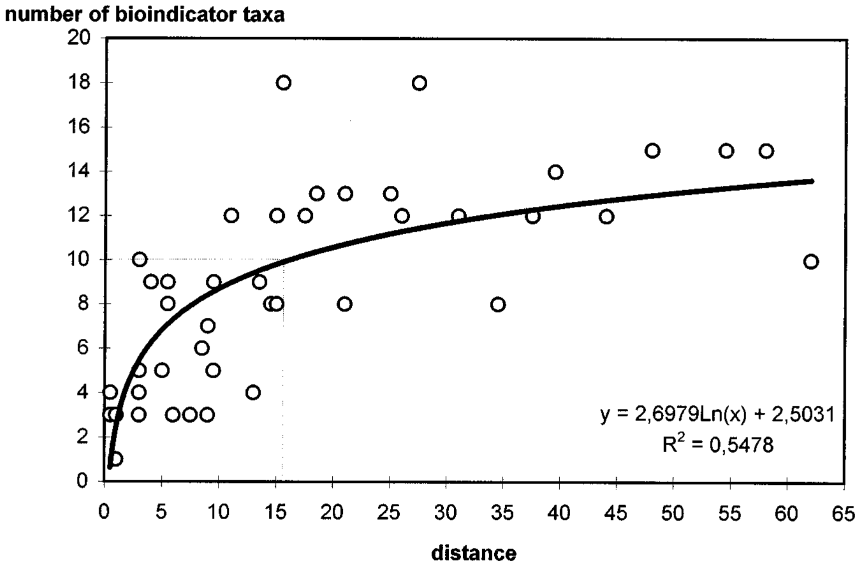

Figure 2. Correlation between the number of bioindicator taxa (Y) and the distance of the sites in kilometers from the source (X) ($r = 0.74$; $P < 0.001$).

and II together but more than 90% for group III and IV. The most eutrophic sites (identified from the chemical analysis) were present in all the TWINSPAN groups: ST1, LG4, LG5 in group I; CH5, LG6 in group II; WE6, WE10 in group III; and group IV. No gradient emerged from the second axis.

The TWINSPAN classification without any chemical data confirmed the same pattern of four relevant groups of sites. DCA ordination still showed the importance of water course size (Figure 4). The TWINSPAN species groups are shown in Figure 5 and Table 3. Group I (upper tributaries) was characterised by the dominance of *Phalaris arundinacea*

Table 2. Species recorded from the Welland. The site code at the top of the table is given in table 1. Authorities follow Stace (1991)

	111122222233333334444 122223334 11 111
	01282346890134569012312901572784678957345346
Angelica sylvestris	-------------1------------------------------
Apium nodiflorum	1113121233311-111---1-111312-1--1---111--11-
Callitriche platycarpa	----------------------1----1----------------
Callitriche stagnalis	-121-1-113-3---------1131-1-12-1------------
Carex acutiformis	---3----1-2--1---------21-------------------
Cirsium palustre	------1-11111--11--1--1---------1---------1-
Elodea canadensis	---------------------------1--2-------------
Epilobium hirsutum	2211122112211122-1112-121211--1211-1-1-1-1--
Equisetum fluviatile	-------------12--1-1------------------------
Equisetum palustre	-1-1111111111-------------11-1-----------11-
Glyceria fluitans	-------------------1------------------------
Juncus effusus	-1--------1------111----1-------------------
Juncus inflexus	------1-1-1-1--1111-------------------------
Mentha aquatica	-------1221--1-11---------1--11--1----------
Oenanthe aquatica	----------1---------------------------------
Petasites hybridus	---------1----------------------------------
Persicaria maculosa	-----------------------------1-1------------
Potamogeton natans	---------22-------1---1---------------------
Potamogeton obtusifolius	------------------1-------------------------
Ranunculus aquatilis	-----------------------------1--------------
Ranunculus repens	-11111111111111111111----1-1----------------
Ranunculus sceleratus	----------1-----------1---------------------
Rorippa nasturtium-aquaticum	---1--1-2-12--111---1-1-12-3-3-11-----------
Scirpus sylvaticus	----------------------1---------------------
Solanum dulcamara	11-1-2111-11112211112-11--111-1111-11---11--
Urtica dioica	1----1--1111-1--1-------1-1-----------------
Veronica anagallis-aquatica	----111----------------11-11-2-1----------1-
Veronica beccabunga	-2------21112111111-1--------2-11--1---1-11-
Amblystegium riparium	------1------------3--2---------------1-----
Rumex sp	-111111111111--111111--1111--11-1-----------
Nymphoides peltata	----------------------1---------------------
Oenanthe fluviatilis	-------------------------------2------------
Iris pseudacorus	---1------1--------------------------------1
Phalaris arundinacea	62121323323322321121211232326213222232233323
Potamogeton crispus	--1----1--323--------53-122---12------31221-
Scrophularia auriculata	-----1--11--1----1-----111---111---1--------
Sparganium erectum	-313-22423433-11-1-131333131-34322--2132-3-3
Zannichellia palustris	-1----2---------------1-1-------------1-----
Alisma plantago-aquatica	---1------------------1---------------1-----
Myosotis scorpioides	-21----1---1------1---1-11-2-1-112-1-----11-
Myriophyllum spicatum	---------------------11------------2--------
Rorippa amphibia	------1------1----1---1-11---1-1-1--1--11-11
Sagittaria sagittifolia	---------------------------1--22-1-------2--
Sparganium emersum	---1---1------------1-11-211-1221-2---211111
Veronica catenata	----------------------1--1-21-------1--1-1--
Cladophora sp	-2111133---11---111-2-333222-51-35333632-3-3
Elodea nuttallii	--2------------------13215---3--1-11113322-1
Butomus umbellatus	---------------------------------11-11--111-
Carex acuta	----------------------------------1---------
Glyceria maxima	-------------------------3------332--2---211
Lemna gibba	--------------------------------523333-----1
Lemna minor	-------1-1111-----1-1-1-121311111333332322-2
Nuphar lutea	-------1-------------------------12---33-1--
Plantago major	--1-
Persicaria amphibia	----------------------------------1-11---11-
Potamogeton pectinatus	------------1-------1-------------3332133323
Potamogeton perfoliatus	-----------------------------2--133231-3-3-5
Rumex hydrolapathum	--1-
Schoenoplectus lacustris	-------3------------------------111-2--1-1--
Typha latifolia	---------------------------------2----------
Rhynchostegium riparioides	---------------------------------1---1------
Fontinalis antipyretica	-------------------------------2---1-2------
Enteromorpha sp	-----------12-----1-1-4-12132231332333214143
Ranunculus penicillatus	-------------------------------3--14-3------
Potamogeton x salicifolius	----------------------------------1---------

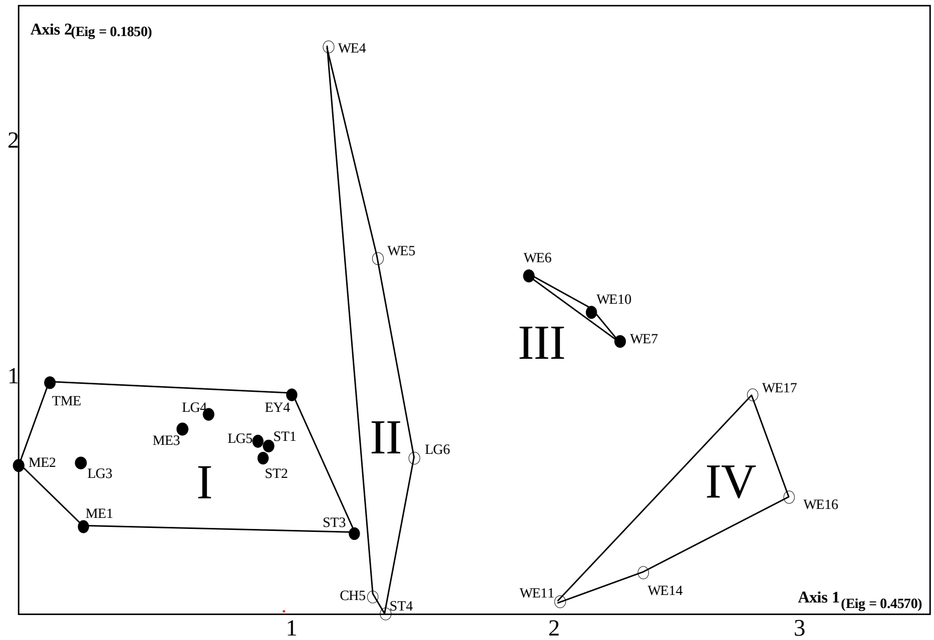

Figure 3. DECORANA ordination of selected sites (with all environmental parameters). Closed solid lines show the groups identified with TWINSPAN classification. Axis 1 represents water course size.

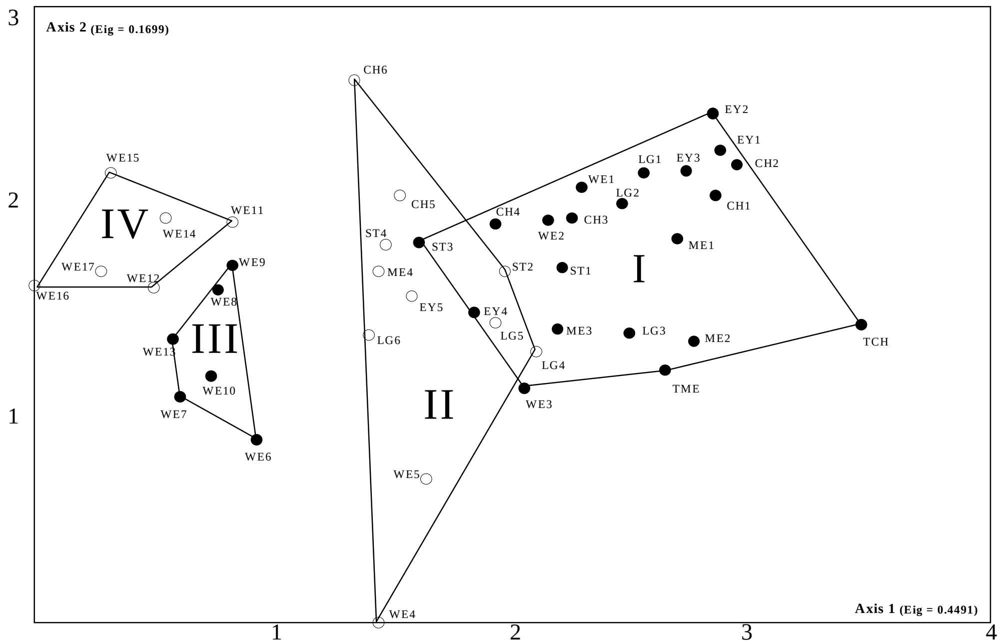

Figure 4. DECORANA ordination of all sites (without chemical data set). Closed solid lines show the groups identified with TWINSPAN classification. Axis 1 represents water course size.

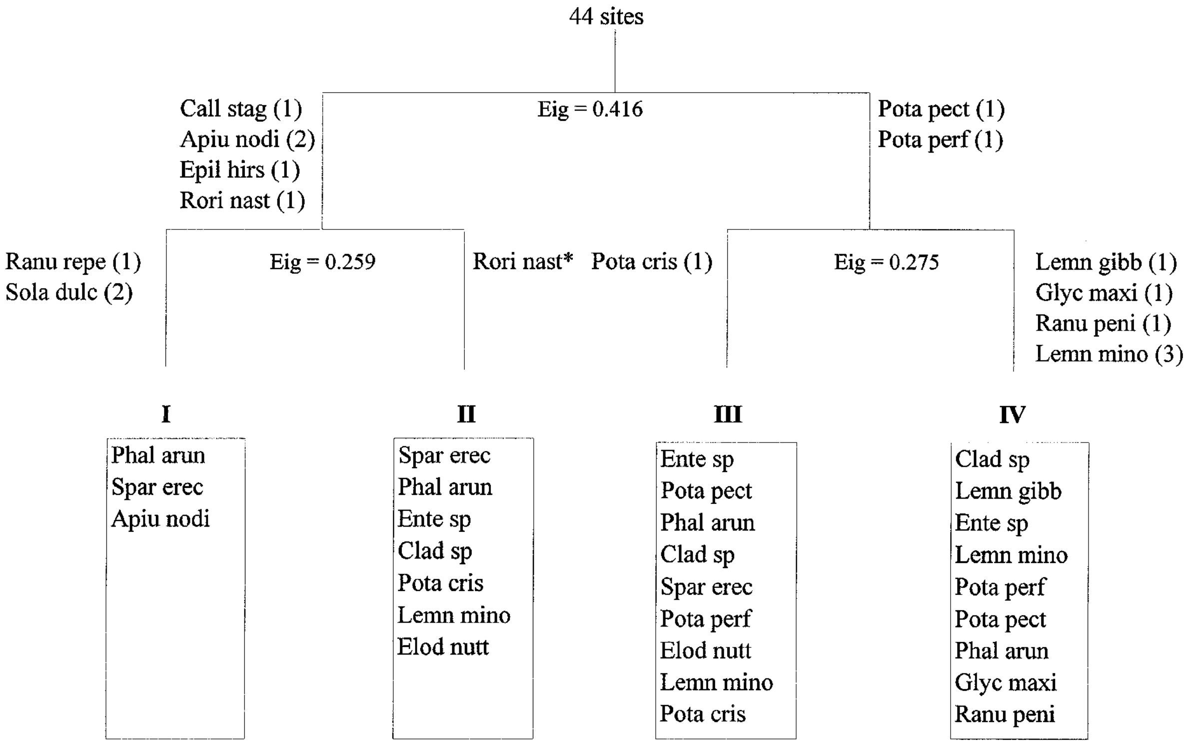

Figure 5. Groups of vegetation identified with TWINSPAN and the data in Table 3. The indicator species for each division are shown in decreasing order of significance. Pseudospecies levels are noted in brackets. ∗ indicates species included from Table 3.

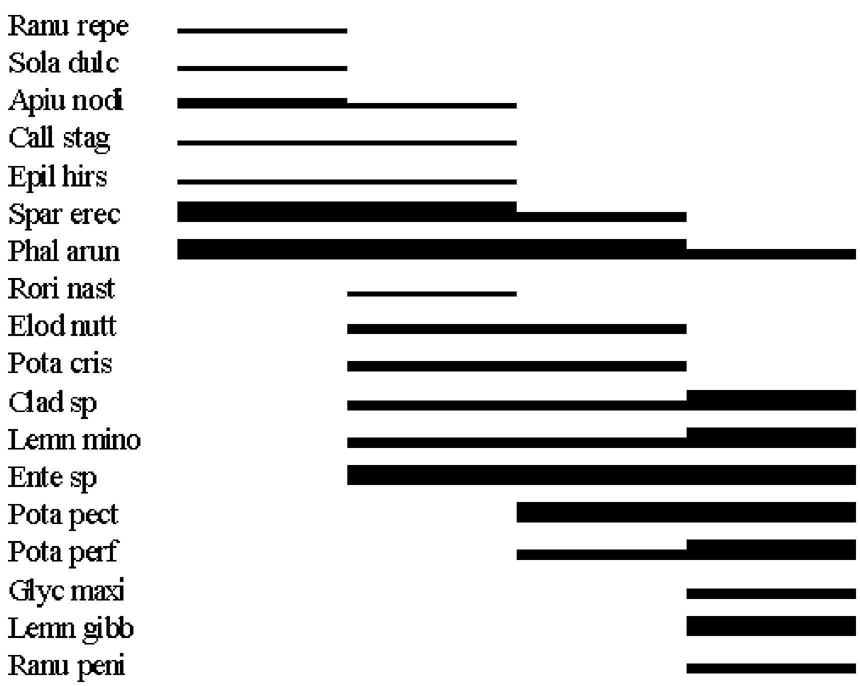

Figure 6. Gradient of vegetation. Only selected species are included. The thickness of the lines indicate the relative frequency-abundance of the species.

Table 3. Frequency and cover coefficient values for each species which was recorded in at least four sites, arranged in species groupings and site groupings. Brackets show the minimun and maximum values recorded

	Group I		Group II		Group III		Group IV	
number of sites	21		11		6		6	
total number of species	14 (5–22)		16 (6–26)		15 (10–23)		17 (16–20)	
number of true aquatic species	4 (0–9)		8 (3–16)		10 (7–15)		12 (10–14)	
overall percentage cover	30 (1–95)		65 (30–95)		65 (50–85)		75 (50–95)	
Apium nodiflorum	V	325	IV	173	III	10	III	10
Callitriche stagnalis	II	162	IV	175	–	–	–	–
Carex acutiformis	I	87	I	29	–	–	–	–
Cirsium palustre	III	9	I	2	I	3	I	3
Epilobium hirsutum	V	139	IV	91	III	7	IV	13
Equisetum fluviatile	I	17	–	–	–	–	–	–
Equisetum palustris	III	10	II	5	II	7	–	–
Juncus effusus	II	5	I	2	–	–	–	–
Juncus inflexus	II	8	–	–	–	–	–	–
Mentha aquatica	II	33	II	5	–	–	I	3
Potamogeton natans	I	29	I	2	–	–	–	–
Ranunculus repens	V	19	I	4	–	–	–	–
Rorippa nasturtium-aquaticum	III	35	III	305	–	–	I	3
Solanum dulcamara	V	70	IV	13	II	3	IV	13
Urtica dioica	II	8	I	4	–	–	–	–
Veronica anagallis-aquatica	I	3	III	36	I	3	–	–
Veronica beccabunga	IV	52	I	20	III	10	II	7
Amblystegium riparium	I	72	I	27	I	3	–	–
Rumex sp.	V	17	III	11	–	–	I	3
Iris pseudacorus	I	2	–	–	I	3	–	–
Phalaris arundinacea	V	979	V	1019	V	1100	V	500
Potamogeton crispus	II	159	IV	790	V	356	–	–
Scrophularia auriculata	II	5	III	11	–	–	I	3
Sparganium erectum	IV	833	V	1165	IV	800	IV	153
Zannichellia palustris	I	15	I	4	I	3	–	–
Alisma plantago-aquatica	I	1	I	2	I	3	–	–
Myosotis scorpioides	II	18	III	36	II	7	III	57
Myriophyllum spicatum	–	–	I	4	–	–	I	50
Rorippa amphibia	I	3	III	9	IV	13	II	7
Sagittaria sagittifolia	–	–	II	56	I	50	I	3
Sparganium emersum	I	3	IV	91	V	67	II	53
Veronica cateneta	–	–	II	33	II	7	I	3
Cladophora sp.	IV	86	IV	1061	IV	800	V	3500
Elodea nuttallii	I	14	III	870	V	603	V	17
Butomus umbellatus	–	–	–	–	III	10	IV	13
Glyceria maxima	–	–	I	136	III	57	IV	600
Lemna gibba	–	–	–	–	I	3	V	2092
Lemna minor	II	7	V	176	V	450	V	1253
Nuphar lutea	I	1	–	–	III	503	II	53
Persicaria amphibia	–	–	–	–	II	7	III	10
Potamogeton pectinatus	I	2	–	–	V	1300	V	803
Potamogeton perfoliatus	–	–	I	27	III	2042	V	807
Schoenoplectus lacustris	I	71	–	–	II	7	IV	60
Fontinalis antipyretica	–	–	I	27	–	–	II	37
Enteromorpha sp.	I	17	V	701	V	1557	V	1300
Ranunculus penicillatus	–	–	I	136	–	–	III	878

and *Sparganium erectum*. *Apium nodiflorum* was also well represented. Group II, included taxa such as *Potamogeton crispus*, *Elodea nuttallii*, *Lemna minor* and *Enteromorpha sp* as abundant. *Rorippa nasturtium aquaticum* (not relevant from TWINSPAN classification) also appeared to be a better indicator species characteristic of group II. Group I and II (upper sites) were both distinguished from the other groups by *Apium nodiflorum*, *Callitriche stagnalis* and *Epilobium hirsutum*. The most relevant species to differentiate group III and IV were *Potamogeton crispus* and *Elodea nuttallii* common in group II and III, and *Lemna gibba*, *Glyceria maxima* and *Ranunculus penicillatus* confined to group IV. Figure 6 illustrates this vegetation gradient throughout the four groups of sites.

Discussion

Two national analyses, both using TWINSPAN, have been undertaken by Holmes (1983) and Rodwell et al. (1995). Each used different concepts, sampling methods and data analysis and so this limits comparison. Holmes (1983) surveyed one kilometre of each site, scored species abundance on a three point scale, and used both river and bank species. He found four different communities on nine sites sampled on the River Welland: A1iii 'highly managed unstable sand rivers'; A2i 'highly managed clay rivers with soft limestone in catchment'; A2iv 'Central England clay rivers'; A4ii 'clay ditches'. The length of the sample stretches necessarily hid irregularities, but the general characteristics (narrow channel, very steep, high sided banks physically uniform, very impoverished flora) of A4ii fit quite well with the upper stretches of the River Welland (WE1, WE2), the Chater and its main tributary (CH1, CH2, CH3, CH4, TCH), and the Medbourne at ME4. Here the vegetation is dominated by the emergent species *Phalaris arundinacea* and *Sparganium erectum* and is very poor in true aquatic macrophytes. These constitute part of the group I. A2i was Holmes' most widespread community. The clay characteristic species (e.g. *Sagittaria sagittifolia*, *Schoenoplectus lacustris*, *Nuphar lutea*) are still present but often scarce. The extension of the algae *Cladophora* sp. and *Enteromorpha* sp., of *Potamogeton pectinatus* and profuse *Lemna gibba*, previously unrecorded, are symptoms of increased eutrophication.

The approach of Rodwell et al. (1995) is based on a phytosociological concept. They used quantitative floristic records (Domin scale), from stands of vegetation relatively homogeneous in composition and structure, in an empirical minimal area (4 or 16 m^2). They distinguished different layers of aquatic vegetation, reflecting the view that such assemblages are distinct communities related to different environmental conditions in particular sites and playing different roles in the successional colonisation of open waters. The coverage of running waters is moreover particularly incomplete (for more comments, see Preston, 1995b). Haslam et al. (1975) had planned to include notes on the sociological affinities of each species; but this has not proved possible partly for lack of information and partly because of continuing disagreement over the standard classification of the water plant communities themselves. Moreover a complete revision of the relevé material is not possible because of the methodological and taxonomical invalidity of much older material (Wiegleb, 1983). Nevertheless the NVC communities recognised by Rodwell et al. (1995) can be recognised (Table 4) within the groups identified in the Welland. Several missing aspects of the NVC – pure stands of *Potamogeton crispus* (groups II & III), *Elodea nuttallii* (group II), *Potamogeton perfoliatus* (groups III & IV) are not recognised and the algae *Cladophora* sp. and *Enteromorpha* sp., both widespread, are not included – weaken its value in running water studies.

Equisetum palustre and *Equisetum fluviatile*, were noted rare in the Anglian region (Holmes, 1995), but were regularly recorded althougth often scarce.

The chemical analysis was limited to soluble nitrates and phosphates. However, rooted macrophytes take more nutrients from the sediment. Consequently a study concerning the validity of the MTR method should include a complete chemical analysis. Also, some effort should be made to distinguish between nutrient pollution and other pollutions as some macrophyte species do not themselves make a distinction (Carlson, 1977): for instance *Potamogeton pectinatus* (Haslam, 1978) or *Amblystegium riparium* (Whitton et al., 1991).

The study indicates that aquatic macrophytes in lowland, naturally nutrient-rich catchments, do show responses to further anthropogenic enrichment which can be detected using phytosociological methods and indices such as MTR. However, at a catchment scale the over-riding factor is stream size and this allows other environmental factors such as field-by-field land

Table 4. Presence of the UK NVC communities in the four species groups identified

	S8	S10	S7	A9	A16	S23	S14	S28	S5	A8	A12	A1	A2	A11	A17
Group I	×	×	×	×	×	×	×	×							
Group II			×	×	×	×	×	×	×						
Group III							×	×	×	×	×				
Group IV							×	×	×	×	×	×	×	×	×

use change, riparian disturbance by cattle or bankside shade to obscure water quality relationships. It is clear that future surveys should select sites where physical parameters are homogeneous. Considering the difficulty of finding homogeneous 100 metre lengths, 50 meters would be enough (Wiegleb, 1981a) and these should ideally be divided into each mesohabitat (Symes et al., 1997). Léglize et al. (1990) had also suggested that the appropriate study level is a stretch with roughtly the same velocity, substrata type and light intensity.

Measurement of physical factors (armoured layer, sediment, flow, temperature, light); other chemical factors liable to influence the macrophyte distribution, particularly sediment nutrient levels, would enable a more detailed analysis such as canonical correspondance analysis (CANOCO (Ter Braak, 1986, 1988)).

The lack of phytosociological survey in running water might reflect the weakness of this concept because of the temporal and spacial heterogeneity of the runing water environment. Southwood (1988) provided an alternative 'habitat templet' concept which is currently being tested elsewhere by taking aquatic macrophytes traits (life history, life form, phenology) to build objective strategic groups of species (Wilby et al., in prep). A full evaluation of the MTR indicator species approach against a thorough phytosociological survey and a habitat templet classification should now be carried out for several catchments with contrasting environmental and anthropomorphic influences.

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