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A botanical classification of standing waters in Great Britain

and a method for the use of macrophyte flora
in assessing changes in water quality

incorporating a reworking of data,
1992

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INTRODUCTION

In "A Nature Conservation Review" (Ratcliffe ed. 1977) standing waters are classified as dystrophic, oligotrophic, mesotrophic, eutrophic, marl or brackish, and a general description is given of the flora and fauna characteristic of each type of water. Few attempts have been made to produce a more detailed classification of the freshwaters of Great Britain using macrophyte vegetation. Holmes (1983) produced a classification of rivers for Britain as a whole, but standing waters have been classified largely on a regional basis. Pearsall (1920) described the vegetation of the Lake District, Spence (1967) investigated the distribution of freshwater plants in Scottish lochs and Seddon (1972) analysed the patterns of vegetation in 120 Welsh lakes.

For more than a decade, detailed surveys of standing waters throughout Great Britain have been carried out by Nature Conservancy Council staff, and a large amount of data on the distribution of aquatic macrophytes has been gathered. This publication describes a recent analysis of the NCC data for standing waters, and provides a classification of sites which can be applied throughout Great Britain. The work has also produced a method of monitoring changes induced by acidification or eutrophication of standing waters.

METHODS

Field survey

A standard method for surveying aquatic macrophytes in standing waters is employed by the Nature Conservancy Council. This entails walking the perimeter of the lake or other water body to record shoreline and shallow water vegetation. Deeper water is sampled by means of a grapnel thrown from the bank at frequent intervals during the perimeter walk. Where possible, a boat is used, and grapnel samples are obtained from the bottom during transects of the lake and passages parallel to the shore. All aquatic plants are recorded on a subjective "DAFOR" abundance scale - dominant; abundant; frequent; occasional; rare.

Since 1975, this method has been used to record the aquatic vegetation of over 1,100 lakes, meres, reservoirs, pools, ponds, gravel pits and canals throughout Great Britain. Data have been assembled from the following sources:

Surveyor	% of sites in database	Area surveyed
Elizabeth Charter (on contract to the NCC Chief Scientist Directorate, alone or leading teams)	54	Lake District and Northern Scotland
Chris Newbold (Chief Scientist Directorate)	16	)
Margaret Palmer (Chief Scientist Directorate)	6	) Throughout Great
Combined survey by Chris Newbold and Margaret Palmer	6	) Britain
Margaret Dickson, Fiona Evans and others (on contract to NCC W Midlands Region)	5	Gloucestershire and Wiltshire
Edinburgh Botanic Gardens (on contract to NCC)	4	Outer Hebrides

England Field Unit, NCC	4	West Midlands
Susan Bell (on contract to NCC NW Scotland Region)	3	Caithness
Hazel Drewitt and Tim Smith (on contract to NCC E Midlands Region)	1	Lincolnshire
Nick Stewart and John Page (independent botanists)	1	Scotland and Worcestershire

Ditch vegetation surveys have not been incorporated in this database because the intensive management of ditch systems, their dimensions and intermittent flow, and the different survey methods employed, make the data unsuitable for inclusion. The distribution throughout Great Britain of the survey sites is shown in FIGURE 1. The concentration of sites in the Lake District and northern Scotland is testimony to the efforts of Elizabeth Charter and her teams of field workers.

At most of the sites single measurements were made of the pH and electrical conductivity of the water. For a minority of sites, water samples were analysed for a variety of parameters, including alkalinity, oxidised nitrogen, ammonium nitrogen, phosphorus, silica, chloride, potassium, calcium, magnesium, iron and aluminium. 114 measurements of alkalinity by titration were carried out by Dr Chris Newbold for sites which he surveyed.

Analyses of data

A computer file was made, containing records of all the macrophyte species, along with their DAFOR abundance ratings, for 1,124 sites. These data were then subjected to TWINSPAN (Two-way Indicator Species Analysis). This computer program was devised by Hill (1979a), and is a sophisticated method of producing an ordered matrix of sites by species, a series of end-groups of sites with similar vegetational characteristics, and a key to those end-groups, based on indicator species.

Two runs of TWINSPAN were made, one with submergent, floating and emergent vegetation, the other with only the 104 species considered to be submergent and floating. The DATAEDIT program (Singer 1980) was subsequently used to draw up species constancy tables for end-groups (ie site types) chosen for examination. The validity of this choice of site types was tested by using the DECORANA (Detrended Correspondence Analysis) program (Hill 1979b), which arranges the individual sites along a number of axes, usually related to environmental parameters.

RESULTS

The analysis based on submergent and floating species alone produced clearer results than that using all species, including emergents. There appeared to be two main reasons for this. Firstly, full records of emergent vegetation were not available for all sites. Secondly, emergent vegetation is often subject to influences (eg grazing or differences in substrate) not experienced by the open water vegetation. The TWINSPAN program was therefore producing skewed results when all the zones of vegetation were included, so it was decided that results based on full lists would be discarded in favour of those for the open water zones alone. It was possible subsequently, using the DATAEDIT program, to formulate lists of emergent species associated with open water site types.

TABLE 1 shows the species occurring at a constancy of more than 20% in the TWINSPAN end-groups finally chosen to represent ten site types. Two of these site types have variants, making a total of 12 end-groups which are recognised. The hierarchy produced by TWINSPAN is shown in TABLE 2. Site types were identified initially by comparing species constancies for groups at various levels in the TWINSPAN hierarchy, in order to decide, in the light of experience in the field, whether or not the groups were sufficiently different to form distinct site types. Use of the DECORANA program confirmed the choice of end-groups. FIGURE 2 shows the relationship between the 10 site types as discerned by DECORANA. The key to site types, produced by TWINSPAN, is given in TABLE 3.

Type 1 is a species-poor group, characterised by submerged Sphagnum, Juncus bulbosus var. fluitans and, less constantly, Potamogeton polygonifolius. Type 2 sites are typified by the last two species, along with Littorella uniflora, Lobelia dortmanna and Potamogeton natans. Type 3 is distinguished from type 2 mainly by the higher incidence of Myriophyllum alterniflorum, Isoetes lacustris and Fontinalis antipyretica. Type 4 contains elements (eg Littorella uniflora, Potamogeton natans and Myriophyllum alterniflorum) of Type 3, but in addition a number of species such as Potamogeton filiformis, P. praelongus and Chara are common. Type 5A consists of a species-rich sub-group characterised by Littorella uniflora, Myriophyllum alterniflorum, Nitella species, Potamogeton berchtoldii and Elodea canadensis. The variant 5B consists of species-poor sites dominated by Potamogeton natans and Nymphaea alba. Type 6 sites usually contain few species apart from Potamogeton pectinatus, Ruppia species and seaweeds such as Fucus ceranoides. Sites in Type 7 have distinct affinities with those of Type 4, in that they often contain Potamogeton filiformis and Chara species, but type 7 sites usually lack Nitella and Myriophyllum alterniflorum. Type 8 sites are poor in open water species, but rich in emergents, and are characterised by Lemna minor and Polygonum amphibium. Type 9 sites are dominated by the water lilies Nuphar lutea and Nymphaea alba. Type 10 has two variants, one characterised by Elodea canadensis and Lemna minor, the other by Potamogeton pectinatus and Chara species.

Indicated in TABLE 4 are emergent species which typify communities as described in National Vegetation Classification (Rodwell 1984) and are most constantly associated with open water site types 1 to 10.

Data on physical and chemical characteristics of sites in the ten types are displayed in TABLE 5 and FIGURE 3.

DISCUSSION

Factors influencing plant distribution

The distribution of aquatic plants, both within and between water bodies, is determined by a number of factors. Pearsall (1920) considered substrate and depth to be the most important factors in the Lake District. Spence (1967) and Seddon (1972) regarded water chemistry of lakes as highly significant, and drew attention to the importance of alkalinity, pH, conductivity and the ratio of Ca + Mg to Na + K in determining the distribution of plants. Ormerod et al. (1987) have shown that assemblages of plants in soft-water streams in Wales are related strongly to pH. Holmes and Newbold (1984) suggest that river plant communities reflect both substrate and water chemistry. Rodwell (1984, 1986-87) has brought together published data on the trophic requirements of swamp, fen and mire vegetation communities. He will be relying strongly on the TWINSPAN classification described here to produce the National Vegetation Classification for aquatic plant communities.

Chemical classifications of water bodies

Ratcliffe (1977) gives these as the characteristics of different types of water:

	Alkalinity (mg/l $CaCO_3$)	Conductivity (μmhos)	pH
Dystrophic	0-2	-	less than 6
Oligotrophic	0-10	-	6-7
Mesotrophic	10-30	-	around 7
Eutrophic	Over 30	-	over 7
Marl	Over 100	-	over 7.4
Brackish	-	Over 500	-

The upper limit of 500 μmhos given by Ratcliffe for the conductivity of fresh water is an under-estimate. Brackish waters have a sodium chloride concentration of at least 500 mg/l, accounting for a conductivity of approximately 1000 μmhos (U.S Department of Agriculture 1954). Other ions also contribute to conductivity, so measurements of less than 1,500 μmhos are seldom encountered in brackish waters.

Vollenweider (1968) defined the trophic categories of waters in terms of nitrogen and phosphorus, as follows:

	mg/l	
	Total P	Inorganic N
Ultra-oligotrophic	<0.005	<0.02
Oligo-mesotrophic	0.005-0.01	0.2-0.4
Meso-eutrophic	0.01-0.03	0.3-0.65
Eu-polytrophic	0.03-0.10	0.5-1.5
Polytrophic (hypertrophic)	>0.10	>1.5

High alkalinity is not invariably associated with eutrophic waters. The Lismore Lochs in Argyll, for instance, have alkalinities of 120-160 mg/l $CaCO_3$, but low levels of nitrogen and phosphorus (Ratcliffe 1977).

Water chemistry of site types

Data on nitrogen and phosphorus concentrations are sparse for the sites in the NCC standing waters database, but pH, conductivity and, to a lesser extent, alkalinity, were measured routinely when the sites were surveyed. Therefore, the last three parameters are employed as indicators of nutrient status, in the knowledge that a minority of sites will be misclassified using these criteria.

FIGURE 3 illustrates the ranges of alkalinity, conductivity and pH for waters in the ten chosen site types. It is obvious that, despite considerable overlap, there is a general trend from low alkalinity, conductivity and pH to high values, with the progression from type 1 to type 10. Type 1 sites have alkalinities below 2 mg/l $CaCO_3$, conductivities below 100 µmhos, and pH generally below 6, but frequently less than 5. Sites in types 2 and 3 generally have alkalinities ranging from 2 to 30 mg/l, conductivities similar to those of type 1, and pH most often between 6 and 7. Type 4 sites encompass a wide range of alkalinities, including over 30% in the marl category. Their conductivities are similarly wide-ranging and their pH usually above neutral. The majority of type 5 sites have water with alkalinities within the 10-30 mg/l (mesotrophic) range, and their conductivities and pH tend to be slightly higher than those of types 2 and 3. Type 6 sites are obviously brackish, mostly with conductivities higher than 5,000 µmhos, far in excess of the usual upper limit of 1,500 µmhos for fresh waters. Some sites in type 7 are also brackish, but the majority have conductivities which are relatively high, but still within the limits for fresh waters. Sites in this group have generally high alkalinities and pH. Sites in types 8, 9 and 10 mostly have alkalinities above 30 mg/l, conductivities over 200 µmhos and pH higher than neutral, although type 9 appears to contain a wider variation than types 8 and 10. A large proportion of type 8 sites fall into the highly alkaline marl category.

It seems reasonable, on this evidence, to allocate the following trophic states to waters of the 10 site types:

Type 1	-	dystrophic
Types 2 and 3	-	oligotrophic
Type 4	-	wide range
Type 5	-	mesotrophic
Type 6	-	brackish
Types 7, 8 and 10	-	eutrophic
Type 9	-	mainly eutrophic, but with some mesotrophic sites.

Marl waters and those which are only slightly saline are not well differentiated in this classification. The former are mainly incorporated into type 7 and the latter are dispersed amongst types 4, 7, 8, 9 and 10. The variety of conditions evident in type 4 sites, which nevertheless form a recognisable group as defined by vegetational characteristics, can be explained by the fact that many of the sites in this group lie in calcareous basins fed by water from acid catchments.

The output from DECORANA (FIGURE 2) shows a clear progression along axis 1 from dystrophic waters (type 1), through oligotrophic lakes (types 2 and 3) to mesotrophic and "mixed" sites (types 5 and 4). The eutrophic types (7, 8, 9, 10) are clumped together next, and the brackish sites (type 6) are placed at the opposite end from the dystrophic ones. The arrangement along axis 4 separates-out the series of eutrophic sites. Axis 1 defines variation in conductivity and pH. The trend on axis 4 is difficult to interpret, but may be associated with the ratio between certain ions.

Data on phosphorus concentrations for a series of lochs in the Central Region of Scotland, surveyed during September 1981, bear out the trophic classification of the site types. Ten of these lochs are classified by their macrophytes as types 2 and 3. The total phosphorus concentrations in water from these lochs lay around or below the level of detection (0.02 mg/l). The mean concentration of this nutrient in the two sites categorised as type 5 was 0.035 mg/l. The remaining site falls into type 10a, and the total phosphorus level of its water was 0.2 mg/l. The mean alkalinities were as follows:

Type 2 (3 sites)	-	4.9 mg/l $CaCO_3$
Type 3 (7 sites)	-	9.7 mg/l $CaCO_3$
Type 5 (2 sites)	-	34 mg/l $CaCO_3$
Type 10a (1 site)	-	97 mg/l $CaCO_3$

The alkalinity values are very close to those suggested for oligotrophic, mesotrophic and eutrophic sites by Ratcliffe (1977), but the total phosphorus levels are slightly higher than the equivalents suggested by Vollenweider (1968).

Geographical distribution of site types

The distribution of sites in types 1-10 is illustrated in FIGURES 3-13. It can be seen that types 1-7 lie predominantly in the north and west of Britain; types 8 and 10 are mainly southern and eastern, and type 9 sites are widespread in England and Wales. Sites characteristic of the ten types are:

Type 1	Smaller lochs on blanket bog in Sutherland Heathland ponds in Woolmer Forest, Hampshire
Type 2	Upland tarns in the Lake District "Blackland" lochs in the Outer Hebrides Peaty lochs in Caithness and Sutherland Pools on the Lizard in Cornwall
Type 3	Large lochs in the Trossachs Lochs on igneous and metamorphic rock in Caithness and Sutherland Wastwater, Buttermere, Coniston Water in the Lake District Loch Lomond Llyn Idwal and Llyn Ogwen, Snowdonia Oak Mere in Cheshire
Type 4	Coastal freshwater lochs in northern Scotland, including many machair lochs in the Outer Hebrides
Type 5	Bassenthwaite Lake, Windermere and Esthwaite Water in the Lake District The Lake of Menteith, Central Region of Scotland Greenlee and Broomlee Loughs, Northumberland
Type 6	Brackish sea-lochs in Orkney and Shetland Loch Obisary, Outer Hebrides
Type 7	Machair lochs with strong marine influence in the Outer Hebrides Lochs on Durness Limestone, Sutherland Lochs on Old Red Sandstone in Caithness and on Orkney
Type 8	Meres in Shropshire, Cheshire and Staffordshire Llyn Coron, Anglesey Fleet Pond, Surrey
Type 9	Calthorpe Broad, Norfolk Haweswater, Lancashire Llanbwchllyn, mid Wales

Type 10a Little-used canals throughout Britain
Semerwater, Yorkshire
Gravel pits in eastern England and elsewhere.

Type 10b Gravel pits in the Cotswolds
Malham Tarn, Yorkshire.

Trophic requirements of individual species

It is obvious (TABLE 1) that some floating and submergent macrophyte species are restricted to nutrient-poor waters, some are typical of nutrient-rich sites, but many are more catholic in their requirements. Species most characteristic of nutrient-poor waters of types 1 to 3 include Juncus bulbosus var. fluitans, Potamogeton polygonifolius, Lobelia dortmanna, Sparganium angustifolium and Myriophyllum alterniflorum. Species strongly associated with the eutrophic types 7 to 10 are Lemna species, Myriophyllum spicatum, Potamogeton pectinatus and, in Scotland, Potamogeton filiformis. The assemblage of species usually found in type 4 sites is drawn from both ends of the spectrum, as might be expected in sites subject to an unusual combination of influences.

Spence (1967), Seddon (1972), Haslam et al. (1975), Ratcliffe (1977) and Newbold & Palmer (1979) all attempted to categorise aquatic plants according to their trophic requirements. The first two authors confined their attention to Scotland and Wales, whereas the others attempted a more general approach. On the basis of experience in the field, and without benefit of sophisticated vegetation analysis, Newbold and Palmer allocated aquatic plants to trophic categories, and devised a system of trophic ranking numbers (TRN). These numbers were not meant to be scores, but were intended as an aid to finding the position of plants within broad bands of alphabetically arranged species, allotted to particular trophic levels. Thus, sites containing plants with TRNs mainly below 22 would be oligotrophic and sites with plants ranked above about 110 would be eutrophic or hypertrophic. Intermediate numbers were allotted to plants thought to be ubiquitous or associated mainly with mesotrophic waters.

TABLE 6 lists all the species in the NCC database which occurred at 5% constancy or more in the TWINSPAN classification for site types 1 (dystrophic), 2 and 3 (oligotrophic), 5 (mesotrophic), 7 ("northern" eutrophic) and 8 and 10 ("southern" eutrophic). Types 4 and 9 are omitted because of their mixture of affinities, and brackish sites (type 6) are excluded because there are so few in the database. The species are ordered, giving a progression from dystrophic to eutrophic, and the strength of the association of each species with each trophic state is indicated. Beside this list are the opinions of the previously-mentioned workers regarding the requirements of each species.

TABLE 7 was drawn up by extracting site-based lists of emergent plants from the database and fitting these to the classification of floating and submergent species constructed by TWINSPAN. Only species occurring at a constancy of 10% or more for each site type are listed in TABLE 7, as the associations are one step removed from the original analysis and so must be treated with caution. Again, the list is annotated with previous opinions.

There is a fair amount of agreement between the various opinions expressed, with some notable exceptions. For instance, Seddon associated Elodea canadensis and Sparganium erectum in Wales mainly with oligotrophic conditions and thought Sparganium minimum was probably confined to eutrophic sites - a very different picture from that given in the analysis for Great Britain.

The general impression given in TABLES 6 and 7 is of a number of obligate eutrophic species grading into a series of species with gradually wider tolerance. Some of these tolerant species may be excluded from eutrophic situations by competition. As Seddon (1972) states:

"....groups tolerant of eu-, meso- and oligotrophic waters comprise a continuous series of species with progressively greater ecological range. No groups are mutually exclusive and there are few pairs of species whose ranges do not overlap at their extremes".

DOME codes and Trophic Ranking Scores (TRS)

The "DOME codes" in TABLES 6 and 7 show the range of tolerance (dystrophic to eutrophic) of each species, as indicated by the TWINSPAN classification. An upper case letter in the code signifies greater confidence than a lower case one. The right hand columns of TABLES 6 and 7 list the "Trophic Ranking Score" (TRS) for each species. TRS is calculated in the following way. The "units" of the DOME code are allotted values of 1 to 10, according to their position in the trophic scale:-

D	1	m	6
d	2	M	7
o	3	m	8
O	4	e	9
o	5	E	10

where D and d = dystrophic
O and o = oligotrophic
M and m = mesotrophic
E and e = eutrophic

Lower case "o" and "m" are allotted two values each. The value chosen in individual cases depends on the upper case symbol or symbols also present in the particular DOME code.

Each species is given a TRS by dividing the total value of the units in the DOME code by the number of the units, to give the mean value. Examples of TRS are:

DO	$\frac{5}{2}$	=	2.5	(the lowest value possible without Sphagna being determined to species)
Om	$\frac{10}{2}$	=	5.0	
DOMe	$\frac{21}{4}$	=	5.3	
oME	$\frac{22}{3}$	=	7.3	
mE	$\frac{18}{2}$	=	9.0	
E	$\frac{10}{1}$	=	10	(the highest value possible)

The average TRS for a whole site is calculated by adding the individual scores and dividing by the number of scoring species. For a hypothetical site containing the following seven species, the average TRS is worked out thus:

	DOME code	TRS
Potamogeton perfoliatus	oME	7.3
P. natans	OME	7.0
Callitriche hamulata	Ome	6.3
Littorella uniflora	OMe	6.7
Isoetes lacustris	Om	5.0
I. setacea	-	-
Juncus bulbosus	DOMe	5.3

$$\text{Average TRS} = \frac{37.6}{6} = 6.3$$

The average TRS gives a more subtle assessment of the trophic status of a site than would be obtained by keying-out a plant assemblage to site type.

Because brackish waters encompass a range of trophic states, salinity tolerance is not included in this scheme.

ASSESSING CHANGES IN AQUATIC FLORA AND WATER QUALITY

A change in trophic state of a site is usually accompanied by a change in macrophyte species composition. If there were a gross change, the site would key-out to a different site type, but smaller shifts caused by acidification or nutrient enrichment can be identified by using the average TRS. As open water plants are more reliable indicators of water chemistry than emergent species, it is best to use only floating and submergent species in calculating average TRS, when looking for indications of a change in water quality. The following examples illustrate the use of this method.

Alpnachersee Lake (Switzerland)

Transects of Alpnachersee Lake, carried out in 1933 and 1983, are illustrated by Harding (Department of the Environment 1987). The submerged and floating species recorded on the two occasions, with their DOME codes and TRS, are as follows:-

Species recorded in 1933	DOME code	TRS	Species recorded in 1983	DOME code	TRS
Chara species	oME	7.3	Nuphar lutea	ME	8.5
Myriophyllum spicatum	mE	9.0	Potamogeton nodosus	-	-
Nuphar lutea	ME	8.5	P. pectinatus	E	10.0
Nymphaea alba	OMe	6.7	P. pusillus	mE	9.0
Potamogeton crispus	mE	9.0	Average TRS		9.2
P. lucens	E	10.0			
P. nodosus	-	-			
P. pectinatus	E	10.0			
Utricularia vulgaris	Om	5.0			
Average TRS		8.2			

The difference is clear, illustrating the eutrophication which has occurred in this polluted lake. The average TRS has increased, despite the fact that the site keys-out to type 10 for both sampling dates. What is not evident from the average TRS is the decline in vegetation cover and the loss of species.

Galloway Lochs

Raven (1985) compared his recent records of the aquatic flora of 23 Galloway lochs with lists compiled by West in 1904/5 (West 1910). Using Seddon's suggestions (Seddon 1972) for the trophic tolerance of aquatic species, he concluded that eutrophication may have occurred in three of the lochs and that ten of them had apparently been subject to various degrees of acidification. In detecting changes, great emphasis was placed on the few species with extreme requirements, including Potamogeton lucens and P. pusillus.

In order to compare Raven's method with the use of average TRS, the scores derived from the early and recent lists of floating and submergent plants were compared (see below). Emergent species were not included in the calculations of average TRS because changes in the substrate of many of the lakes, caused by artificially raised water levels, may have affected the species composition regardless of changes in water quality. Raven carried out two surveys of Loch Fleet, the first by walking around the loch shore (the method used to survey the rest of the Galloway lochs), the other by sampling from a boat. The presence of abundant submerged Sphagnum was revealed only during the second survey. More comprehensive surveys of the other lochs might show a widespread distribution of Sphagnum, which would obviously reduce average TRS.

Loch	Submergent and floating vegetation - average Trophic Ranking Score				Suggested change in trophic state	
	1904/5		1983/4		Raven	Palmer
!Fleet	5.7		5.2		*No change	Acidification
Enoch	5.2		5.5		No change	?Slight eutrophication
Long) Lochs of	5.2		5.3		No change	Little change
Round) Glenhead	5.2		5.2		No change	No change
Macaterick	5.4		5.6		No change	Little change
!Riecawr	5.3	(9)	5.9	(11)	Slight eutrophication	Eutrophication
Skae	6.0		6.35		Strong acidification	?Slight eutrophication
Finlas	5.4		5.8		Eutrophication	?Slight eutrophication
Harrow	5.4		5.25		No change	Little change
Howie	6.0		6.1		Strong acidification	Little change
Lochinvar	6.8		7.0		Slight acidification	Little change
!Dee	5.1	(11)	5.6	(10)	No change	Eutrophication
!Whinyeon	6.8	(6)	6.3	(9)	Acidification	Acidification
!Lochenbreck	5.2	(7)	6.15	(11)	Eutrophication	Strong eutrophication
Skirrow	6.1		6.5		No change	?Slight eutrophication
Maberry	6.6		6.3		Acidification	?Slight acidification
Ronald	6.3		6.5		Acidification	Little change
Trool	6.0		6.25		Strong acidification	Little change
!Stroan	5.5	(11)	6.0	(12)	Slight acidification	Eutrophication
Woodhill	6.8		6.5		Acidification	?Slight acidification
White	7.2		7.05		Slight acidification	Little change
Clonyard	5.9		6.1		No change	Little change
Minnoch	3.5		**		No change	-

* No change was inferred by using Seddon's indicator species, but the presence of Sphagnum implied acidification.

** No open water vegetation was recorded in 1983.

! Lochs which show marked change, as indicated by TRS. The numbers of scoring species are shown in parenthesis.

FIGURE 14 shows the relationships between average TRS (for the 1983/4 data) and both pH and conductivity, for 22 lochs surveyed by West and Raven. Although all these lochs would be classified as type 3, there is obviously a range of trophic states represented. It is not yet possible to be certain how much of a shift in average TRS is a significant indication of a change in trophic state, but 0.5 is taken as a provisional threshold.

Palaeolimnological studies of diatoms in lake sediments (Flower et al. 1987 and Anderson et al. 1986) have shown that acidification has been going on in both Loch Enoch and Round Loch of Glenhead throughout the twentieth century, but that Loch Fleet has become acidified only since the mid 1970s. Loch Dee and Loch Skirrow have shown long-term mild tendencies towards acidification, but there has been a rise in pH in Loch Skirrow since 1940 (Flower et al. 1987). The primary cause of acidification in Galloway lochs is thought to be atmospheric deposition, but forestry operations have been implicated in the recent acidification of Loch Fleet (Anderson et al. 1986).

Comparisons of average TRS for 1904/5 and 1983/4 data suggest marked acidification in Loch Fleet and Loch Whinyeon, both considered by Raven to have become more acidic. The average TRS imply considerable eutrophication in four Lochs - Riecawr, Dee, Lochenbreck and Stroan. Raven considered that Lochs Riecawr and Lockenbreck had been subject to enrichment, but he regarded Loch Stroan as slightly acidified. Neither Raven's method nor the TRS method suggests acidification in Loch Enoch or Round Loch of Glenhead. This implies either that phytoplankton is more sensitive than macrophytic vegetation to changes in water quality, or that the macrophyte lists for the Galloway Lochs are incomplete, possibly lacking Sphagnum for some sites. Liming of inflows to Loch Dee has been practised in recent years (Raven 1985), which may account for the rise in average TRS. The greatest rise in average TRS - 0.95 units - is shown by Lochenbreck Loch, which has an extensive hay meadow on its shores and may be receiving nutrients from fertilizer application (Raven 1985).

Lakes in Wales

Two of the Welsh lakes whose flora was recorded in the 1960s (Seddon 1972) were re-surveyed some years later by Newbold and Palmer. There was very little difference in average TRS for the two dates for Llyn Fanod (see below), but a considerable decrease for Llyn Fach, whose catchment has recently been afforested. At the latter site, in 1988, Sphagnum auriculatum and Juncus bulbosus were abundant in the open water, but neither of these species is mentioned by Seddon for this site. Unfortunately, Seddon's lists do not include bryophytes, so it is impossible to tell whether or not Sphagnum is a newcomer. The possibility remains that Llyn Fach has become acidified as a result of the planting of conifers around its shores.

Llyn Fanod (grid ref. SN 6064)

Open water species	DOME code	TRS	Seddon (1972)	Newbold (survey 1977)
Callitriche stagnalis	omE	7.7	NR	/
Elatine hexandra	M	7.0	/	NR
Fontinalis antipyretica	Ome	6.3	NR	/
Isoetes setacea	-	-	/	NR
Juncus bulbosus	DOMe	5.3	NR	/
Littorella uniflora	OMe	6.7	/	/
Lobelia dortmanna	Om	5.0	/	/
Nitella sp.	OMe	6.7	NR	/
Nuphar lutea	ME	8.5	/	/
Nymphaea alba	OMe	6.7	/	/
Potamogeton natans	OME	7.0	/	/
P. polygonifolius	DOm	3.7	/	/
Scirpus fluitans	dOm	4.0	/	NR
Subularia aquatica	O	4.0	NR	/
Utricularia minor	dOm	4.0	NR	/
Number of scoring species			8	12
Average TRS			6.1	6.0

Llyn Fach (grid ref. SN 9003)

Open water species	DOME code	TRS	Seddon (1972)	Palmer (survey 1988)
Isoetes lacustris	Om	5.0	/	NR
Isoetes setacea	-	-	/	/
Juncus bulbosus	DOMe	5.3	NR	/
Littorella uniflora	OMe	6.7	/	/
Lobelia dortmanna	Om	5.0	/	/
Myriophyllum alterniflorum	OMe	6.7	/	NR
Potamogeton polygonifolius	DOm	3.7	/	/
Scirpus fluitans	dOm	4.0	/	/
Sparganium angustifolium	dOm	4.0	/	/
Sphagnum auriculatum	DO	2.5	NR	/
Number of scoring species			7	7
Average TRS			5.0	4.5

NR = not recorded
/ = present

A number of problems, some common to most surveillance and monitoring exercises, arise when using the average TRS to indicate change. A major difficulty is that of ensuring that the sampling and recording techniques used on different occasions are consistent. Another problem arises because of the lack of information about natural fluctuations in the abundance and distribution of species. The loss of Elodea, for instance, may be due to cyclical population changes rather than changes in water chemistry. Physical change in water bodies is seldom documented while it is occurring, so it is often very difficult to account for changes in flora. Loss or gain of species may be due to hydroseral progression or changes in factors such as water depth, substrate or management practice, rather than water chemistry. No account is taken in the average TRS of the relative abundance of species, nor of the presence of filamentous algae or blooms of phytoplankton, and these are all important considerations. Flowing waters have not been included in this scheme, and DOME codes are lacking for many aquatic plants. Nevertheless, use of the DOME code and average TRS appears to be useful for surveillance and monitoring, perhaps because this uses the whole macrophyte community, rather than relying on a few "indicator" species. What remains to be done is the refining and thorough testing of this method on sites where palaeolimnology or studies of phytoplankton or water chemistry indicate change.

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TABLE 1 TWINSPAN CLASSIFICATION OF STANDING WATER SITES - SUBMERGENT AND FLOATING VEGETATION

Site type	1	2	3	4	5		6	7	8	9	10	
					A	B					A	B
Potamogeton polygonifolius	II	IV	III									
Utricularia intermedia		II										
Lobelia dortmanna		IV	III		II							
Sparganium angustifolium		II	III									
Isoetes lacustris			III									
Subularia aquatica			II									
Myriophyllum alterniflorum		III	IV	IV	V*							
Sparganium minimum					II							
Juncus bulbosus	V*	IV	V*	II	III							
Scirpus fluitans		II										
Sphagnum spp.	IV											
Nymphaea alba		III			III	V*				IV		
Potamogeton alpinus					II							
Nitella spp.			II		IV*							
Callitriche hamulata			II		II							
Littorella uniflora		IV	V*	V*	V*		II	III				
Apium inundatum				II								
Potamogeton natans		IV	III	III	III	IV*		II		II	III	
Glyceria fluitans			III	II				II	II			
Potamogeton gramineus				III	III			II				
Fontinalis antipyretica			III	II	II			II		II		
Potamogeton perfoliatus			II	IV	III			II			II	
Potamogeton obtusifolius					III						II	
Potamogeton berchtoldii				II	IV			II			III	
Callitriche stagnalis			II	II				II	IV	II	II	
Elodea canadensis					IV*				II	II	IV*	II
Nuphar lutea					II				III	V*	II	
Lemna minor									IV	III	IV	
Lemna trisulca										III	II	
Elodea nuttallii												III
Potamogeton lucens												II
Sparganium emersum											II	II
Polygonum amphibium					II			II	IV	II	III	II
Zannichellia palustris								II	III			
Enteromorpha spp.							II				II	
Myriophyllum spicatum				II				III			III	III
Potamogeton crispus					II			II			III	
Potamogeton pectinatus				II			IV*	III			III	IV
Potamogeton pusillus				II	II			II			II	III
Callitriche hermaphroditica				II	II			II				
Chara spp.				III	III*			III		II	II	IV
Fucoids							III					
Ranunculus baudotii				II				III				
Ruppia spp.							IV*					
Hippuris vulgaris				II				IV		II		
Potamogeton filiformis				III				III				
No. of sites in group	48	192	322	72	52	34	15	127	70	28	73	85
Av. no. spp. per site (submergent & floating)	3	7	9	10	13	4	3	8	7	7	10	6
Av. no. spp. per site (submergent, floating + emergent)	7	14	17	19	24	11	6	16	24	19	22	15

Constancy classes
V = 80+ to 100%
IV = 60+ to 80%
III = 40+ to 60%
II = 20+ to 40%

* = cover value high
(frequent to abundant)

'Species' numbers include
bryophytes and algae
determined to genus only.

Note
Ultra-oligotrophic, high altitude lakes, containing only bryophytes, are not included.

TABLE 2 TWINSPAN HIERARCHY - SUBMERGENT AND FLOATING VEGETATION

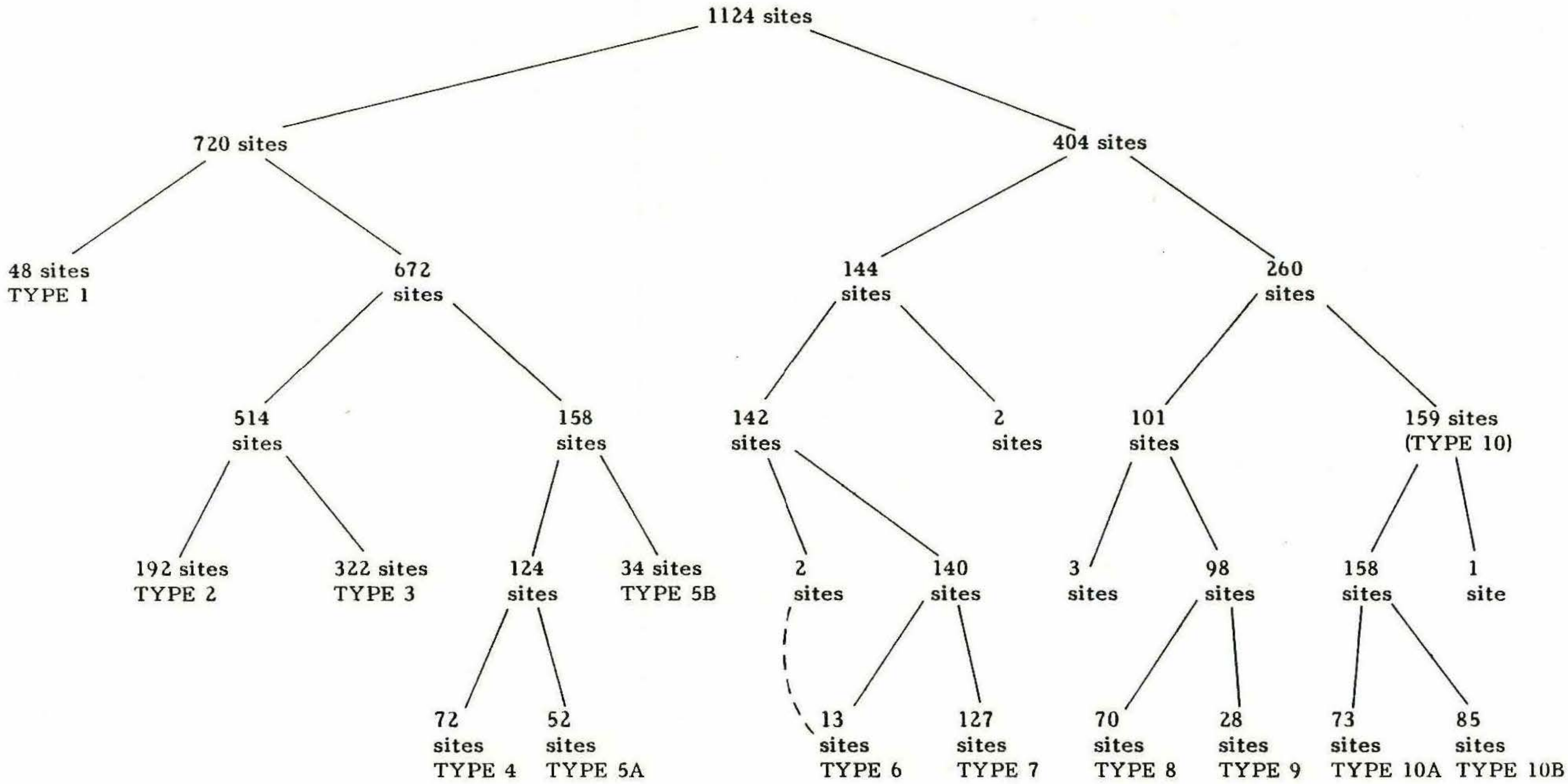


TABLE 3 KEY TO STANDING WATER SITE TYPES (SUBMERGENT AND FLOATING SPECIES)

Indications of minimum abundance levels are given in the key, according to the DAFOR scale:

Dominant	(never a requirement)
Abundant	(never a requirement)
Frequent	
Occasional	
Rare	(minimum abundance level required, unless stipulated otherwise)

	-1	+1	Score	
1	Juncus bulbosus Myriophyllum alterniflorum Littorella uniflora Lobelia dortmanna Potamogeton polygonifolius	Potamogeton pectinatus Polygonum amphibium	-1 or less .... 0 or more	go to 2 go to 3
2	Sphagnum (at least occasional)	Littorella uniflora Myriophyllum alterniflorum (at least occasional) Potamogeton natans	-1 or less .... 0 or more	Type 1 go to 4
3	Potamogeton filiformis Hippuris vulgâris Ranunculus baudotii Littorella uniflora (at least occasional)	Elodea canadensis Lemna minor Nuphar lutea	-1 or less .... 0 or more	go to 5 go to 6
4	Juncus bulbosus (at least occasional) Lobelia dortmanna (at least occasional) Potamogeton polygonifolius Isoetes lacustris Sparganium angustifolium	Potamogeton gramineus Potamogeton perfoliatus (at least occasional)	-1 or less .... 0 or more	go to 7 go to 8
5	Ruppia species Fucoid species (at least occasional)	Chara species Hippuris vulgaris Myriophyllum spicatum Potamogeton filiformis Ranunculus baudotii Polygonum amphibium	0 or less .... 1 or more	Type 6 Type 7
6	Nuphar lutea Callitriche stagnalis	Myriophyllum spicatum Chara species Potamogeton pectinatus Potamogeton pusillus Elodea nuttallii	0 or less .... 1 or more	go to 9 go to 10 (Type 10)
7	Nymphaea alba (at least occasional)	Fontinalis antipyretica Isoetes lacustris Glyceria fluitans (at least occasional) Callitriche hamulata	0 or less .... 1 or more	Type 2 Type 3

	-1	+1	Score	
8	Littorella uniflora Myriophyllum alterniflorum Potamogeton perfoliatus Potamogeton gramineus Chara species Potamogeton berchtoldii	Nymphaea alba (at least occasional)	-1 or less .... 0 or more	go to 11 Type 5B
9	Callitriche stagnalis Zannichellia palustris Polygonum amphibium	Nymphaea alba (at least occasional) Nuphar lutea (at least frequent) Lemna trisulca (at least frequent) Hippuris vulgaris	0 or less .... 1 or more	Type 8 Type 9
10	Lemna minor Elodea canadensis (at least frequent) Potamogeton crispus Potamogeton berchtoldii Potamogeton natans	Chara species (at least occasional) Elodea nuttallii (at least occasional)	-1 or less .... 0 or more	Type 10A Type 10B
11	Potamogeton filiformis (at least occasional)	Elodea canadensis Nitella species	0 or less .... 1 or more	Type 4 Type 5A

TABLE 4

NATIONAL VEGETATION CLASSIFICATION COMMUNITIES MOST COMMON IN EMERGENT FRINGES OF STANDING WATER SITE TYPES

Site type	1	2	3	4	5		6	7	8	9	10		Codes of likely
					A	B					A	B	NVC communities
Emergent species													
Eriophorum angustifolium	III	III	II										Many mire communities
Juncus effusus	IV	III	IV	III	IV	III		II	IV	II	IV	III	M5/M6c
Carex rostrata	III	IV	IV	II	V	IV			II	II	II		M4/M5/M8/M9/S9/S27
Menyanthes trifoliata	II	IV	III	III	III	III		II		II			) M1/M5/M9/S27
Potentilla palustris	II	II	II	III	III	III			II	II			)
Equisetum fluviatile		III	III	III	IV	III		III	II	II	III	III	S10
Eleocharis palustris		II	III	IV	IV	II	II	V	II		III	III	S19
Phragmites australis		II		II	III	III			IV	IV	II	II	S4/S25/S26
Iris pseudacorus				III	II			II	IV	III	III	II	M28
Phalaris arundinacea					III				IV	II	III	II	S28
Scirpus lacustris					II	III				III	II	III	S20
Carex paniculata									III	II			S3
Carex acutiformis									III	II		II	S7
Typha latifolia									III	III	III	IV	S12
Carex elata									II				S1
Typha angustifolia									II	II			S13
Carex riparia									II	II	II		S6
Sparganium erectum										III	III	II	S14
Glyceria maxima											II		S5
Site category	Dys-trophic	Oligotrophic		Oligo/eutrophic	Mesotrophic		Brackish		Eutrophic				

Constancy classes

V = 80+ to 100%
IV = 60+ to 80%
III = 40+ to 60%
II = 20+ to 40%

TABLE 5 PHYSICAL CHARACTERISTICS OF STANDING WATER SITE TYPES

Site type	Water: Usual pH	Water: Usual conductivity (μmhos)	Water: Usual alkalinity (mg/l $CaCO_3$)	Water: Category	Substrate	Geology/ soil	Altitude (m) Percentages are of sites in NCC database	Distribution in GB	Comments
1	3.5-5.5	50-200 (mostly < 100)	Negative to 2	Dystrophic	Peat; rarely sand	Bogs on acid rock or soil	Mostly below 200	Mainly northern	Typical of blanket bog, but can occur on lowland heath.
2	5-7.5 (mostly <7)	10-200	0-25	Oligotrophic	Fine to coarse; often peat	Base-poor rocks (e.g. gneiss, granite)	c. 40% above 200	North and west	Oligotrophic sites heavily influenced by peat. Often small.
3	5-7.5 (mostly <7)	10-200	0-25	Oligotrophic	Predominantly coarse (stones, boulders) but some peat	Base-poor rocks (e.g. gneiss, granite)	c. 40% above 200	Mainly north and west	Oligotrophic sites less heavily influenced by peat than type 2.
4	7-9	100-700	25-200	Oligotrophic with eutrophic influence	Fine to coarse	Usually sedimentary rock; substrate often base-rich (e.g. Old Red Sandstone, machair sand)	c. 25% above 200	Mainly coastal Scotland, especially Northern & Western Isles	Often coastal water bodies, in calcareous basins with acid inflows.
5	6-8 (mostly around 7)	50-300	10-50	Mesotrophic	Fine to coarse	Wide variety; often slightly base-rich	c. 30% above 200	Mainly north and west	An uncommon type, over-represented in the NCC database.
6	8-9	5,000-35,000	-	Brackish (oligohaline to mesohaline)	Fine to coarse	Wide variety	Sea level	Northern & Western Isles of Scotland	This type probably also occurs on the mainland of Scotland.
7	7.5-9.5	300-750 occasionally up to 15,000	50-200	Eutrophic; often marl; sometimes oligohaline	Fine to coarse	Usually sedimentary rock; substrate base-rich (e.g. Old Red Sandstone, limestone, machair sand)	Mostly below 200	Mainly coastal Scotland, especially Northern & Western Isles	Similar to type 4, but with less influence from acid inflows.

Site type	Water				Substrate	Geology/ soil	Altitude (m)	Distribution in GB	Comments
	Usual pH	Usual conductivity (µmhos)	Usual alkalinity (mg/l $CaCO_3$)	Category					
8	7-8.5	200-750	50-250	Eutrophic; often marl	Predominantly fine	Mainly base-rich rocks or glacial drift	Below 200	Lowlands throughout Britain	Open water, often species-poor, but emergent fringe typically rich.
9	6.5-8.5	100-750	10-200	Mainly eutrophic; sometimes marl	Predominantly fine	Mainly sedimentary rocks	Mostly below 200	Mainly England and Wales	Floating-leaved communities dominant. Water-lilies may be introduced.
10	6.5-8.5	100-750	25-200	Eutrophic, sometimes marl	Predominantly fine	Sedimentary rocks, often limestone	Mostly below 200	Lowlands throughout Britain	Submergent communities well developed. Includes a number of canals and gravel-pits.

TABLE 6 TROPHIC REQUIREMENTS OF SUBMERGENT AND FLOATING SPECIES ACCORDING TO TWINSPAN CLASSIFICATION

Site type	Dystrophic 1	Oligotrophic 2+3	Mesotrophic 5	'Northern' eutrophic 7	'Southern' eutrophic 8+10	DOME code	Trophic requirements according to: Spence	Seddon	Haslam et al.	Ratcliffe	Newbold & Palmer (TRN shown)		Trophic ranking score (TRS)
No. of sites	48	514	86	127	228								
!Sphagnum species*	━	━				DO	Poor	-	-	-	-		2.5
!Potamogeton polygonifolius	━	━	- - -			DOm	-	?DO	O	D	O	4	3.7
Scirpus fluitans*	- - -	━	- - -			dOm	Poor	-	DO	D Base-poor	DO	6	4.0
Sparganium angustifolium	- - -	━	- - -			dOm	-	?DO	DO	D Base-poor	DO	7	4.0
Utricularia minor*	- - -	━	- - -			dOm	-	-	DO	D	DO	10	4.0
Subularia aquatica*		━				O	Poor	U	O	Base-poor	O	8	4.0
Utricularia intermedia*		━				O	-	-	DO	D Base-poor	DO	9	4.0
Lobelia dortmanna		━	- - -			Om	Poor	?DO	DO(E)	DM Base-poor	DO	11	5.0
Isoetes lacustris		━	- - -			Om	Poor	?DO	DO	D Base-poor	DO	3	5.0
Utricularia vulgaris agg.*		━	- - -			Om	-	-	M	?U	M	41	5.0
Juncus bulbosus var. fluitans	━	━	━	- - -		DOMe	Poor	?DO	DO (E)	U	DOM	44	5.3
Sparganium minimum*		━	━			OM	-	?E	M	D	M	29	5.5
Potamogeton alpinus*		━	━			OM	-	?DO	OME	?U	U	73	5.5
!Pilularia globulifera*		- - ? - -	? - -			om	-	-	M	M	OM	35	5.5
!Apium inundatum*		━	- - -	- - -		Ome	-	O	OM	U	OM	20	6.3
Callitriche hamulata		━	- - -	- - -	- - -	Ome	-	U	-	U	OM	23	6.3
Fontinalis antipyretica		━	- - -	━	- - -	Ome	U	-	-	-	-		6.3
Myriophyllum alterniflorum		━	━	- - -		OMe	U	U	O(M)	DM Base-poor	O	18	6.7
Littorella uniflora		━	━	━		OMe	U	U	OME	U	U	61	6.7
Nymphaea alba		━	━		- - -	OMe	-	U	(O)E	U	OM	49	6.7
Nitella species		━	━	- - -	- - -	OMe	-	-	-	-	-		6.7
Potamogeton natans		━	━	━	━	OME	-	U	OME	U	U	74	7.0
!Glyceria fluitans		━	- - -	━	- - -	OmE	-	U	(O)M(E)	U	M	47	7.0
Potamogeton gramineus		- - -	━	━		oMe	U	?ME	OME	U	U	64	7.0
Ranunculus peltatus*		- - -	━	- - ? -		oMe	-	-	(O)ME	-	U	48	7.0
Nuphar pumila*			━			M	-	-	OM(E)	D Base-poor	M	24	7.0
!Elatine hexandra*			━			M	Poor	-	M	M Base-poor	M	33	7.0
Potamogeton perfoliatus		- - -	━	━	- - -	oME	U	O	M(E)	U	U	135	7.3
Chara species		- - -	━	━	━	oME	U	-	-	-	-		7.3
Elodea canadensis		- - -	━		━	oME	-	O	ME	U	U	71	7.3
Potamogeton berchtoldii		- - -	━	━	━	oME	-	O	ME	U	OM	27	7.3
!Callitriche stagnalis		- - -	- - -	━	━	omE	-	?ME	ME	U	U	142	7.7
!Hippuris vulgaris		- - -	- - -	━	- - -	omE	-	?E	ME	Base-rich	U	147	7.7
Potamogeton obtusifolius*			━	- - -	- - -	Me	-	ME	(O)M(E)	U	OM	25	8.0
Potamogeton praelongus*			━	━		ME	Mod. rich	-	ME	M Base-rich	ME	94	8.5
Ranunculus trichophyllus*			━	━		ME	-	?E	ME	Base-rich ?M	U	75	8.5
Callitriche hermaphroditica*			━	━	- - -	ME	-	-	ME	DM Base-poor	M	38	8.5
Nuphar lutea			━		━	ME	-	U	(M)E	U	U	143	8.5
Myriophyllum spicatum			- - -	━	━	mE	Rich	E	ME	Base-rich	ME	148	9.0
!Polygonum amphibium			- - -	━	━	mE	-	ME	(O)ME	?U	U	140	9.0
Potamogeton crispus*			- - -	━	━	mE	-	E	(O)ME	M Base-rich	U	139	9.0
Potamogeton pusillus			- - -	━	━	mE	-	?E	MEB	Base-rich B	ME	95	9.0
Lemna minor			- - -	- - -	━	mE	-	ME	OME	Base-rich	U	137	9.0
Ranunculus aquatilis*			- ? - -	- ? - -	━	mE	-	O	(O)ME	U	U	70	9.0
Potamogeton filiformis*				━		E	Mod. rich	-	EB	M Base-rich B	E	122	10.0
Potamogeton friesii*				━		E	-	-	E	Base-rich	E	123	10.0
Ranunculus baudotii*				━		E	-	-	EB	B	E	133	10.0
Ruppia species*				━		E	-	-	-	B	-		10.0
Potamogeton pectinatus				━	━	E	Mod. rich	E	(M)EB	Base-rich B	ME	149	10.0
Zannichellia palustris*				━	━	E	-	-	EB	Base-rich B	E	150	10.0
Ceratophyllum demersum*					━	E	Rich	ME	MEB	Base-rich B	ME	144	10.0
Elodea nuttallii*					━	E	-	-	-	-	U	72	10.0
Lemna trisulca*					━	E	-	E	M	Base-rich	ME	89	10.0
Potamogeton lucens*					━	E	Rich	?E	E	Base-rich	E	124	10.0
Potamogeton trichoides*					━	E	-	-	M(E)	Base-rich	ME	96	10.0
Ranunculus circinatus*					━	E	-	ME	ME	Base-rich	ME	98	10.0
!Ranunculus hederaceus*					━	E	-	-	OME	M	U	65	10.0
!Sparganium emersum*					━	E	-	-	(O)ME	Base-rich	ME	102	10.0

━ = strongly associated with trophic category (20% or more constancy within category or 5-19% constancy but 20% or more of the occurrences of species with fewer than 100 records)

- - - = weakly associated with trophic category (5-19% constancy and less than 20% of the occurrences of species with fewer than 100 records. For species with 150 or more records, at least 5 must be within the category)

? = borderline

D = dystrophic; M = mesotrophic; B = brackish

O = oligotrophic; E = eutrophic; U = ubiquitous or occupying a broad range of nutrient requirements

* = species with fewer than 100 records; ! = species which may occur as emergents

TABLE 7 TROPHIC REQUIREMENTS OF EMERGENT SPECIES

	Dys-trophic	Oligo-trophic	Meso-trophic	'Northern' eu-trophic	'Southern' eu-trophic	DOME code	Trophic requirements according to: Seddon	Haslam et al.	Ratcliffe	Newbold & Palmer (TRN shown)		Trophic ranking score (TRS)
Site types	1	2 + 3	5	7	8+10							
No. of sites	48	514	86	127	228							
Sphagnum species	——	——				DO	-	-	-	-		2.5
Eriophorum angustifolium	——	——				DO	-	(D)O(M)	-	DO	17	2.5
Carex lasiocarpa*		——				O	-	-	-	U	55	4.0
Carex limosa*		——				O	-	OME	-	DO	13	4.0
Carex nigra	——	——	--?---	——		DOme	-	-	-	O	14	5.0
Carex rostrata	——	——	——	——	-----	DOMe	U	OM	-	OM	22	5.3
Potentilla palustris	——	——	——	------	------	DOMe	-	OM	DM Base-poor	OM	28	5.3
Menyanthes trifoliata	——	——	——	——	-----	DOMe	-	DO	U	U	52	5.3
Veronica scutellata		------	------			om	-	OM	-	OM	26	5.5
Juncus effusus	——	——	——	——	——	DOME	-	OM	-	U	51	5.5
Ranunculus flammula	——	——	——	——	——	DOME	-	DOME	U	OM	26	5.5
Agrostis stolonifera	——	——	------	——	——	DOmE	-	OME	-	U	53	5.5
Hydrocotyle vulgaris	------	——	——	——	-----	dOME	-	OME	D Base-poor	U	59	5.8
Equisetum fluviatile	------	——	——	——	——	dOME	U	OME	M Base-poor	U	57	5.8
Eleocharis palustris	------	——	——	——	——	dOME	U	(O)M(E)	U	U	56	5.8
Caltha palustris		——	——	——	——	OME	-	OME	U	U	54	7.0
Phragmites australis		------	——	------	——	oME	U	OME	UB	U	138	7.3
Mentha aquatica		------	——	——	——	oME	-	ME	U	U	77	7.3
Iris pseudacorus		------	——	——	——	oME	-	variable	U	U	60	7.3
Scirpus lacustris		------	------	------	——	omE	U	OME	U	U	141	7.7
Myosotis laxa		------	------	——	-----	omE	-	-	U	ME	90	7.7
Phalaris arundinacea			——	------	——	ME	-	ME	UB	U	78	8.5
Typha latifolia			——		——	ME	?ME	ME	M Base-rich	ME	146	8.5
Sparganium erectum			——	------	——	ME	?O	ME	Base-rich	U	103	8.5
Myosotis scorpioides			------	——	——	mE	-	(O)ME	U	U	62	9.0
Alisma plantago-aquatica			------		——	mE	?ME	?(M)E	U	U	109	9.0
Nasturtium officinale agg.*				——	——	E	-	(O)M(E)	M Base-rich	U	97	10.0
Solanum dulcamara					——	E	-	-	-	-		10.0
Ranunculus sceleratus*					——	E	-	EB	-	E	111	10.0
Typha angustifolia*					——	E	?E	ME	M Base-rich	ME	145	10.0
Veronica beccabunga*					——	E	-	(O)ME	U	U	76	10.0
Apium nodiflorum*					——	E	-	ME	Base-rich	U	106	10.0
Berula erecta*					——	E	-	M(E)	Base-rich	U	81	10.0
Carex acutiformis*					——	E	-	E	-	U	110	10.0
Carex elata*					——	E	-	ME	-	U	84	10.0
Carex paniculata*					——	E	-	E	-	E	113	10.0
Carex pseudocyperus*					——	E	-	ME	-	U	85	10.0
Carex riparia*					——	E	-	E	-	E	114	10.0
Glyceria maxima*					——	E	-	E	Base-rich	E	116	10.0
Polygonum hydropiper*					——	E	-	-	-	U	68	10.0
Rumex hydrolapathum*					——	E	-	E	Base-rich	U	100	10.0

—— = strongly associated with trophic category (20% or more constancy within the group or 10-19% constancy but 20% or more of the occurrences of species with fewer than 100 records)
--- = weakly associated with trophic category (10-19% constancy and less than 20% of the occurrences of species with fewer than 100 records)
? = borderline
D = dystrophic
O = oligotrophic
M = mesotrophic
E = eutrophic
B = brackish
U = ubiquitous or occupying a broad range of nutrient requirements
* = species with fewer than 100 records

Fig. 1 Distribution of sampling sites throughout Great Britain

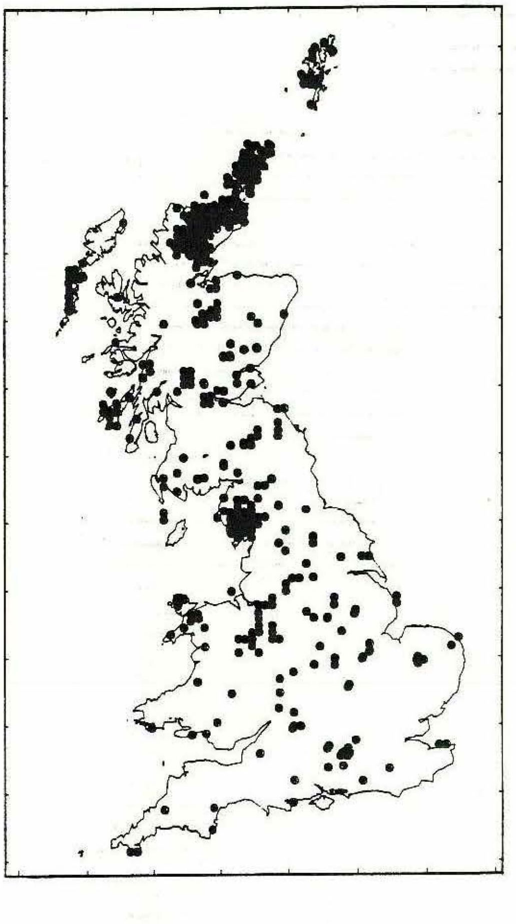


Fig. 2 DECORANA plot showing relationships between site types

Fig. 3 Chemical and physical characteristics of site types

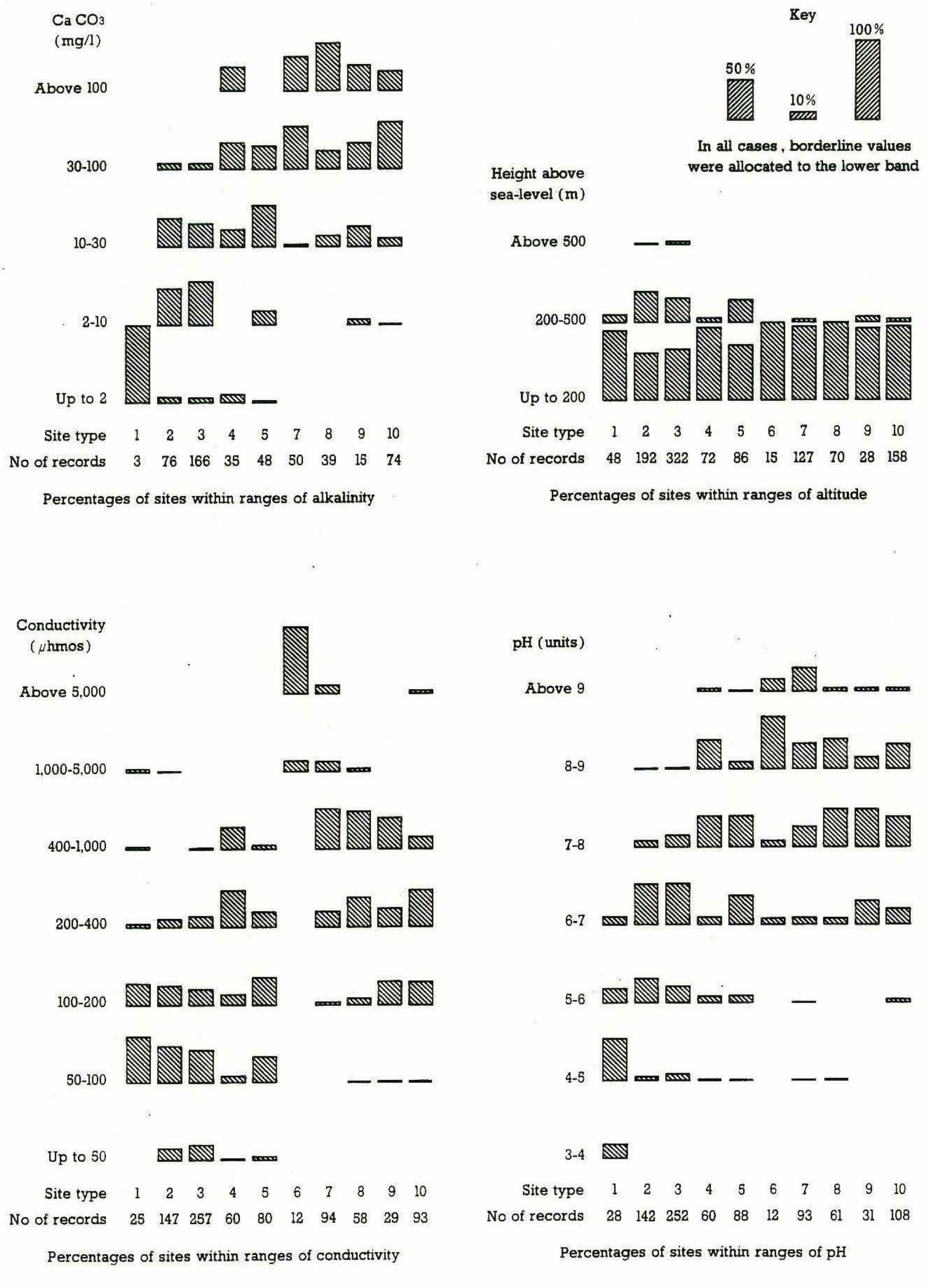


Fig. 4 Distribution of sites in type 1

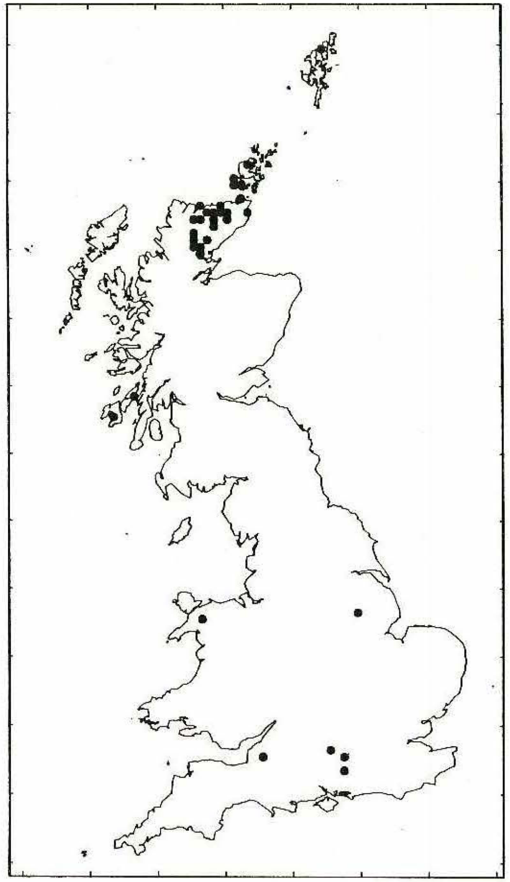


Fig. 5 Distribution of sites in type 2

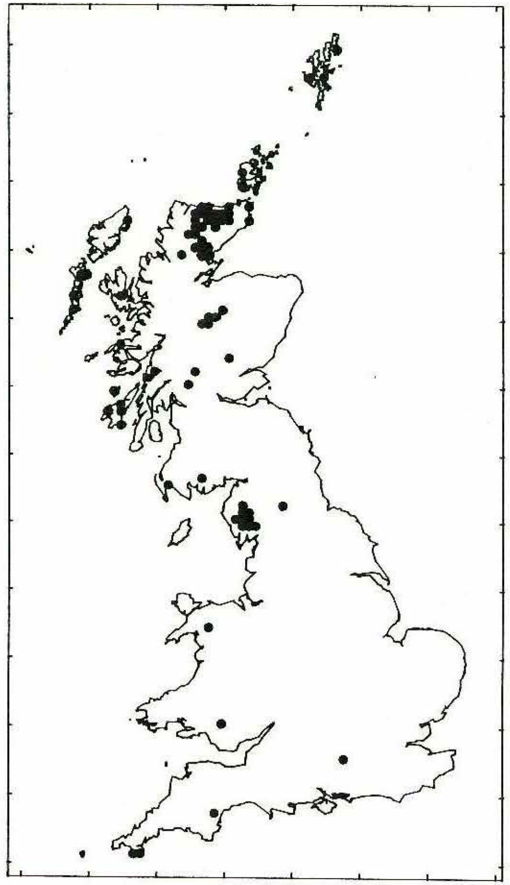


Fig. 6 Distribution of sites in type 3

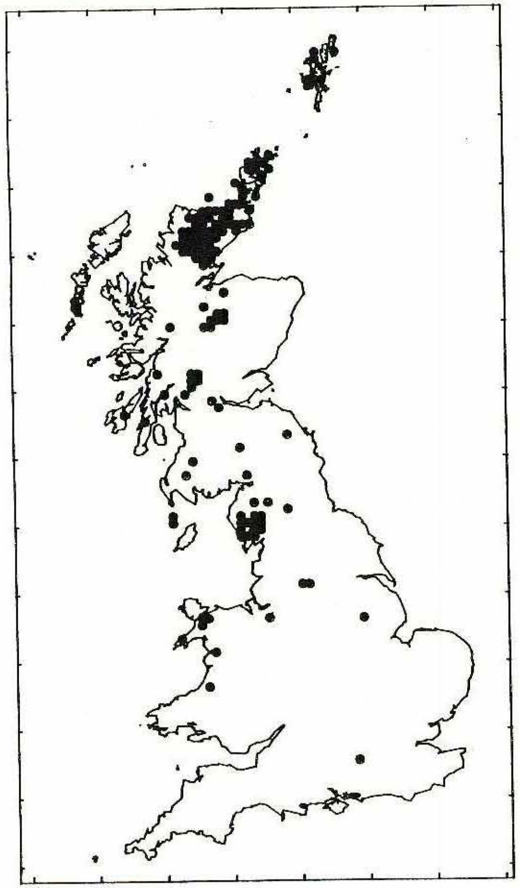


Fig. 7 Distribution of sites in type 4

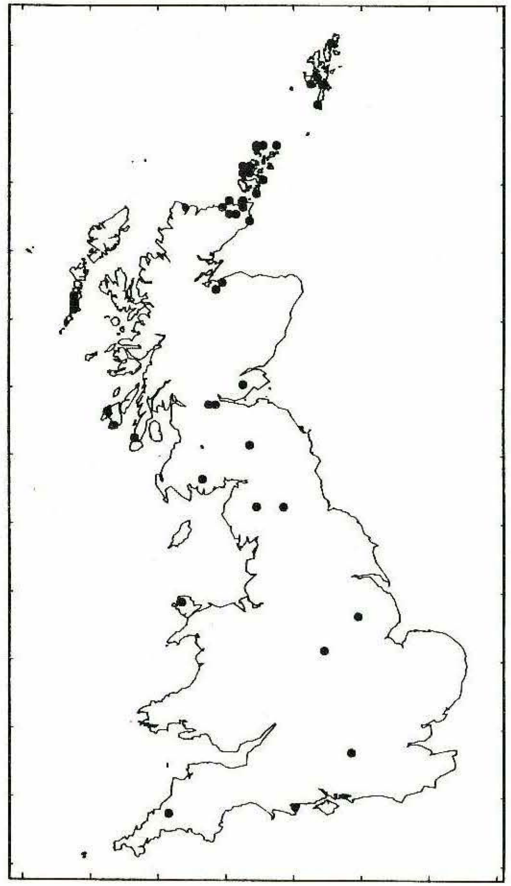


Fig. 8 Distribution of sites in type 5

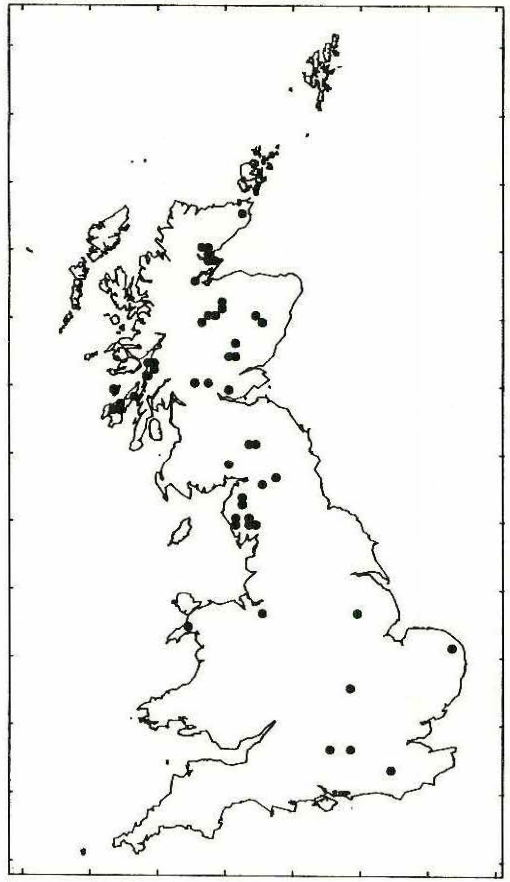


Fig. 9 Distribution of sites in type 6

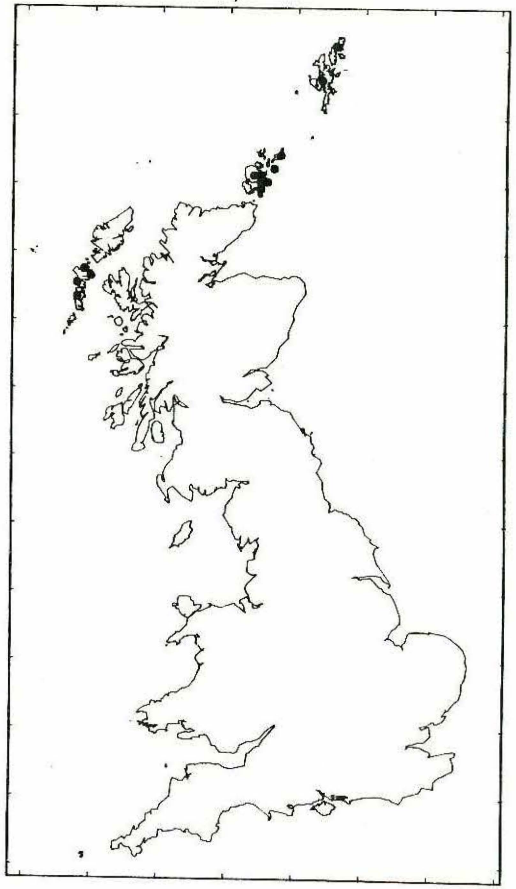


Fig. 10 Distribution of sites in type 7

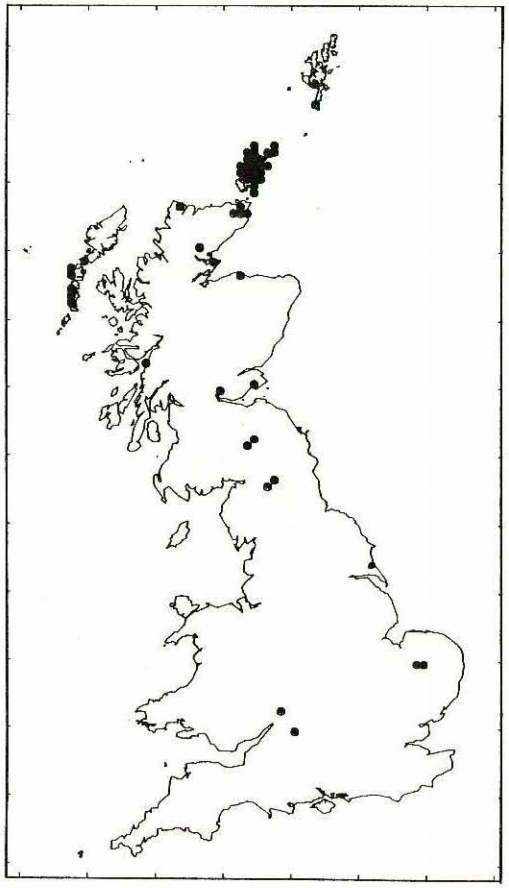


Fig. 11 Distribution of sites in type 8

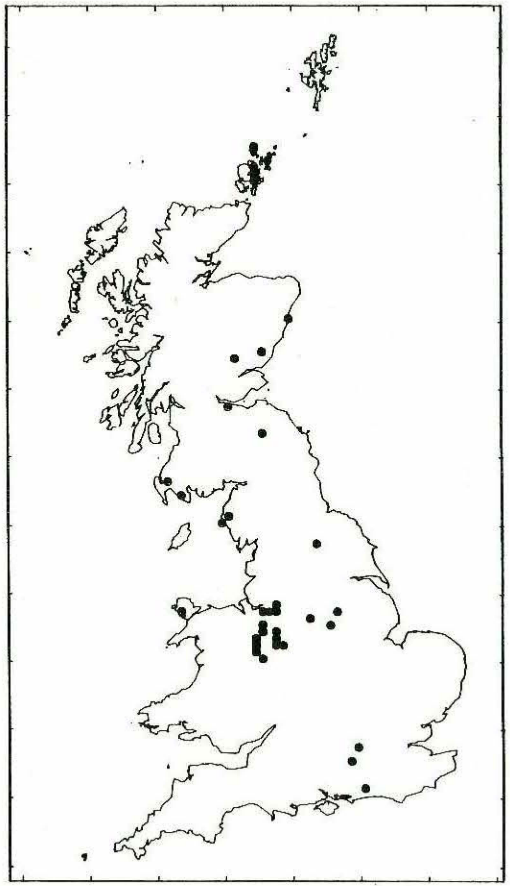


Fig. 12 Distribution of sites in type 9

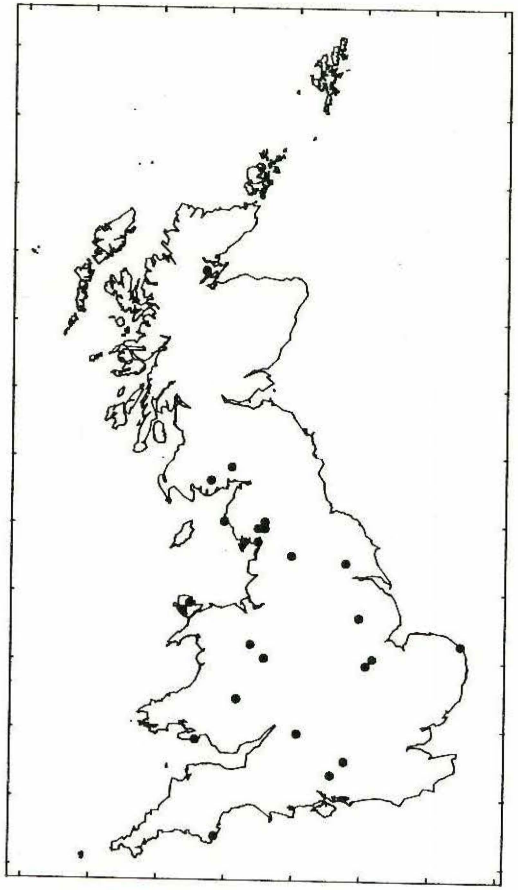


Fig. 13 Distribution of sites in type 10

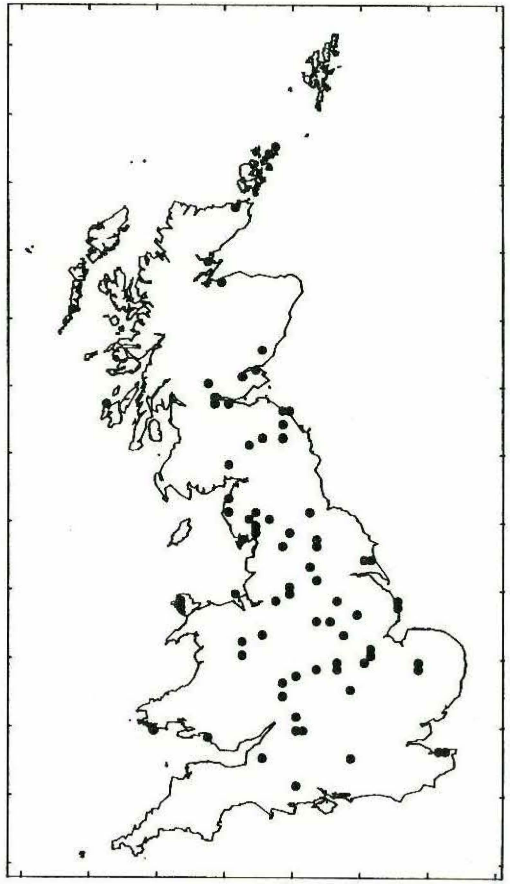
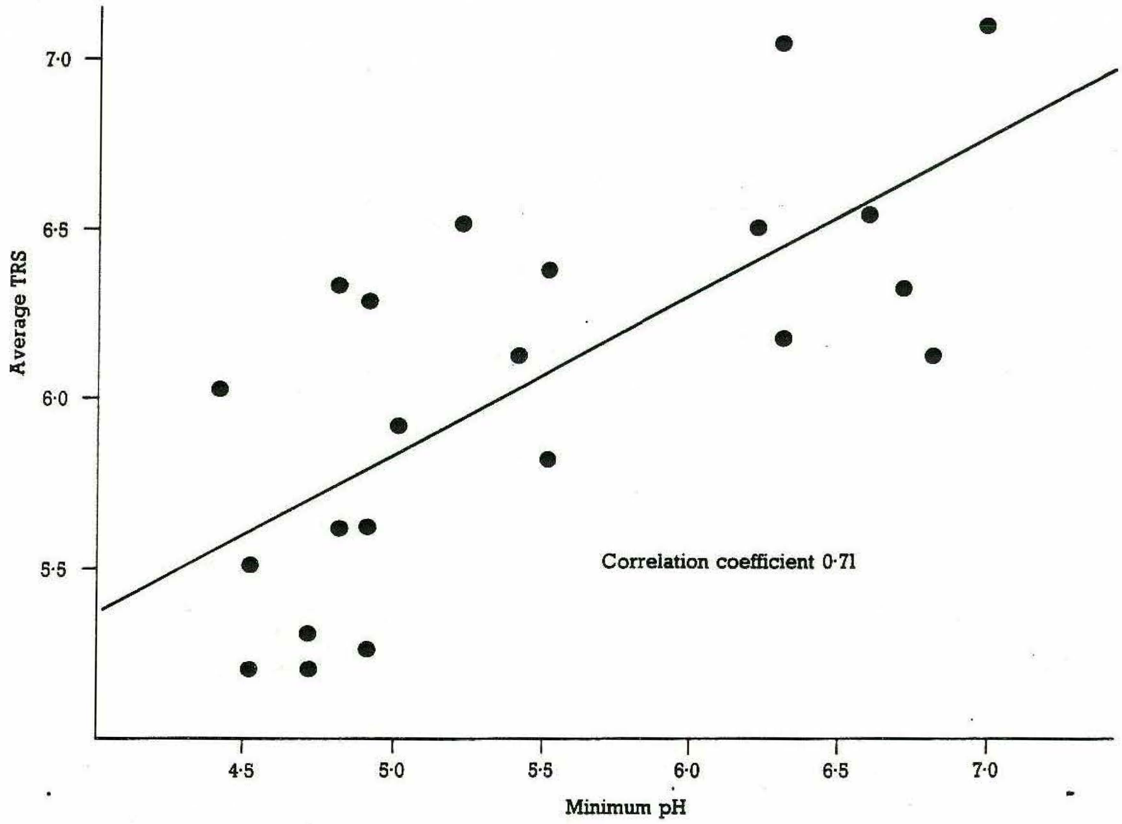
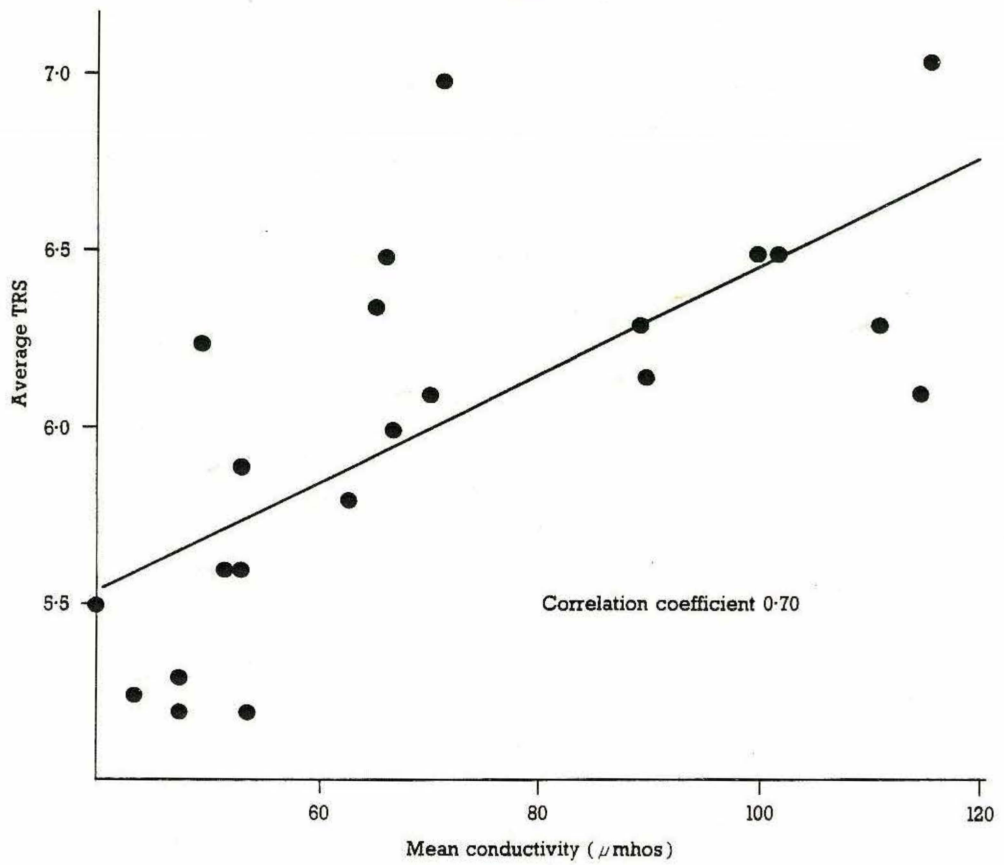


Fig. 14 The relationships between average trophic ranking score (TRS), pH and conductivity for Galloway Lochs





Addendum

Revision of DOME codes and Trophic Ranking Scores

Information from the classification of standing water vegetation was reworked in 1992. As a result, DOME codes and Trophic Ranking Scores for submergent, floating and emergent plant species have been revised, as shown in the following tables (cf. Tables 6 and 7). Also, the relationship of site types to water chemistry was refined, as illustrated in the following figures (cf. Fig. 3).

Palmer, M.A., Bell, S.L., & Butterfield, I. 1992. A botanical classification of standing waters in Britain: applications for conservation and monitoring. *Aquatic Conservation: Marine and Freshwater Ecosystems, 2*: 125-143.

Margaret Palmer
Head, Species Conservation Branch
Joint Nature Conservation Committee

4 September 1992

Trophic requirements of submergent and floating species

	Dystrophic Type 1 (48 sites)	Oligotrophic Types 2 & 3 (514 sites)	Mesotrophic Type 5 (85 sites)	Eutrophic-northern Type 7 (127 sites)	Eutrophic-southern Types 8,9,10 (256 sites)	No. of records	DOME code	TRS
Sphagnum spp.	++	++	?			79	DO	2.5
Potamogeton polygonifolius	+	++				320	d0	3.0
Sparganium angustifolium	+	++				247	d0	3.0
Juncus bulbosus	++	++	+			512	DOm	3.7
Scirpus fluitans	+	++	+			86	d0m	4.0
Utricularia minor	++	++	++			57	DOM	4.0
Subularia aquatica		++				83	0	4.0
Utricularia intermedia		++	?			81	0	4.0
Lobelia dortmanna		++	+			304	0m	5.0
Isoetes lacustris		++	+			212	0m	5.0
Callitriche hamulata		++	+			156	0m	5.0
Myriophyllum alterniflorum		++	++			404	0M	5.5
Nitella spp.		++	++			165	0M	5.5
Utricularia vulgaris agg.		++	++			88	0M	5.5
Sparganium minimum		++	++			70	0M	5.5
Potamogeton alpinus		++	++			61	0M	5.5
Nuphar pumila		+	++			28	oM	6.0
Elatine hexandra		+	++		?	23	oM	6.0
Fontinalis antipyretica		++	+	+		243	0me	6.3
Glyceria fluitans		++	+	+	+	264	0me	6.3
Littorella uniflora		++	++	+		496	0Me	6.7
Potamogeton natans		++	++	+	+	434	0Me	6.7
Nymphaea alba		++	++		+	228	0Me	6.7
Apium inundatum		++	++	++		62	0ME	7.0
Potamogeton obtusifolius		+	++	+	++	81	oME	7.3
Potamogeton praelongus		+	++	++		27	oME	7.3
Potamogeton perfoliatus		+	++	++	+	194	oME	7.3
Potamogeton berchtoldii		+	++	++	++	170	oME	7.3
Potamogeton gramineus		+	++	++		120	oME	7.3
Hippuris vulgaris		+	+	++		156	omE	7.7
Callitriche stagnalis		+	+	++	++	188	omE	7.7
Ranunculus peltatus		?	++	++	?	26	ME	8.5
Callitriche hermaphroditica			++	++	+	69	ME	8.5
Chara spp.			++	++	++	244	ME	8.5
Potamogeton pusillus			++	++	++	125	ME	8.5
Potamogeton crispus			++	++	++	99	ME	8.5
Ranunculus trichophyllus			++	++	++	30	ME	8.5
Ranunculus aquatilis			++	++	++	28	ME	8.5
Ranunculus hederaceus			++	?	++	18	ME	8.5
Callitriche obtusangula			++	?	++	13	ME	8.5
Elodea canadensis			++		++	180	ME	8.5
Nuphar lutea			++		++	129	ME	8.5
Eleocharis acicularis			++		++	16	ME	8.5
Polygonum amphibium			+	++	++	202	mE	9.0
Lemna minor			+		++	140	mE	9.0
Sparganium emersum			?		++	56	E	10.0
Elodea nuttallii			?		++	56	E	10.0
Lemna trisulca			?		++	53	E	10.0
Ranunculus circinatus			?		++	42	E	10.0
Potamogeton lucens			?		++	40	E	10.0
Ceratophyllum demersum			?		++	28	E	10.0
Potamogeton filiformis				++		75	E	10.0
Ranunculus baudotii				++		67	E	10.0
Potamogeton pectinatus				++	++	169	E	10.0
Myriophyllum spicatum				++	++	165	E	10.0
Zannichellia palustris				++	++	76	E	10.0
Potamogeton friesii				++	++	27	E	10.0
Oenanthe aquatica				?	++	12	E	10.0
Potamogeton trichoides					++	17	E	10.0

++ records more than expected number - strong association
\+ records 50-100% of expected number - weak association
? fewer than 5 records, so weak association not confirmed

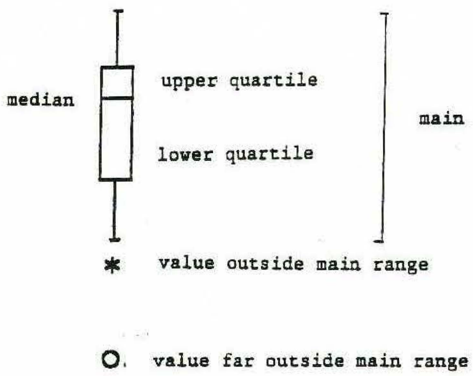
Trophic requirements of emergent species

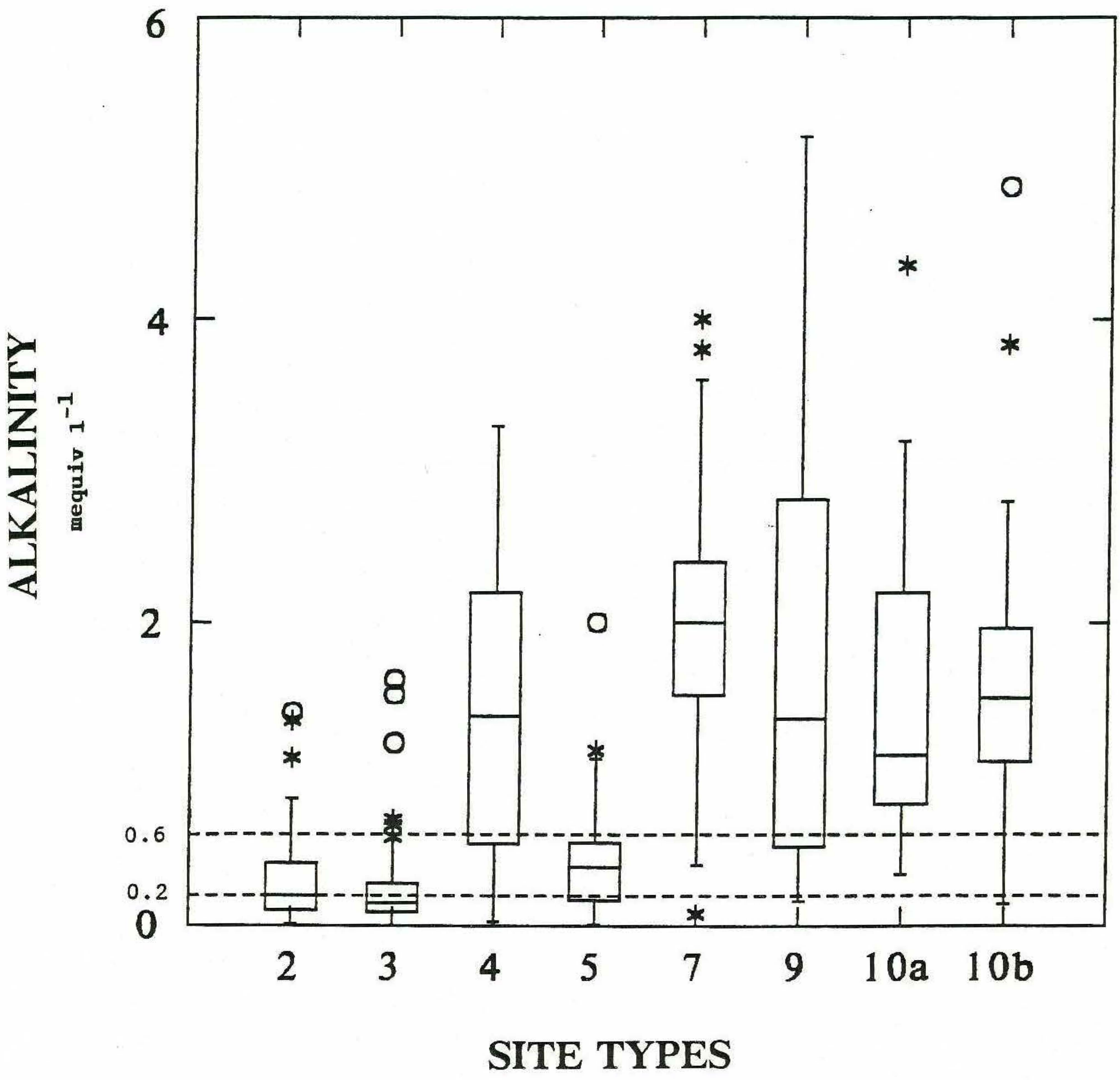
	Dystrophic Type 1 (48 sites)	Oligotrophic Types 2 & 3 (514 sites)	Mesotrophic Type 5 (85 sites)	Eutrophic-northern Type 7 (127 sites)	Eutrophic-southern Types 8,9,10 (256 sites)	No. of records	DOME code	TRS
Eriophorum angustifolium	++	++				251	DO	2.5
Sphagnum spp.	++	++	+			117	DOm	3.7
Carex limosa	?	++				31	O	4.0
Lythrum portula		++	?			22	O	4.0
Baldellia ranunculoides		++		?		21	O	4.0
Carex rostrata	+	++	++			503	dOM	4.3
Carex nigra	++	++		+		336	DOe	4.7
Menyanthes trifoliata	++	++	++	+		393	DOMe	5.3
Ranunculus flammula	+	++	+	+		601	dOme	5.3
Juncus effusus	++	++	++		++	566	DOME	5.5
Potentilla palustris	+	++	++	+	+	268	dOMe	5.5
Carex lasiocarpa		++	++			82	OM	5.5
Carex aquatilis		++	++	?		28	OM	5.5
Agrostis stolonifera	+	+		++	++	342	doE	5.7
Veronica scutellata		++	+	+		109	Ome	6.3
Equisetum fluviatile		++	++	++	+	484	OME	7.0
Hydrocotyle vulgaris		++	++	++	+	270	OME	7.0
Equisetum palustre		+	++	+	+	240	oMe	7.0
Eleocharis palustris		+	++	++	+	536	oME	7.3
Caltha palustris		+	++	++	+	357	oME	7.3
Phragmites australis		+	++	+	++	260	oME	7.3
Galium palustre		+	++	+	++	191	oME	7.3
Scirpus lacustris		+	++	+	++	188	oME	7.3
Myosotis secunda		+	++	?	++	51	oME	7.3
Carex vesicaria		+	++		++	47	oME	7.3
Oenanthe crocata		+	?		++	23	oE	7.5
Myosotis laxa		+	+	++	++	145	omE	7.7
Mentha aquatica			++	++	++	343	ME	8.5
Phalaris arundinacea			++	+	++	200	ME	8.5
Sparganium erectum			++	+	++	210	ME	8.5
Typha latifolia			++		++	193	ME	8.5
Alisma plantago-aquatica			++		++	166	ME	8.5
Carex elata			++		++	43	ME	8.5
Cicuta virosa			++		++	26	ME	8.5
Cladium mariscus			++		++	20	ME	8.5
Iris pseudacorus			+	++	++	247	mE	9.0
Myosotis scorpioides			+	++	++	172	mE	9.0
Glyceria maxima			?	?	++	47	E	10.0
Typha angustifolia			?		++	59	E	10.0
Polygonum hydropiper			?		++	43	E	10.0
Carex pseudocyperus			?		++	42	E	10.0
Nasturtium officinalis agg.				++	++	93	E	10.0
Apium nodiflorum				++	++	54	E	10.0
Scirpus tabernaemontani				++	++	31	E	10.0
Veronica anagallis-aquatica				++	++	31	E	10.0
Carex paniculata				+	++	61	E	10.0
Carex riparia				?	++	56	E	10.0
Solanum dulcamara					++	130	E	10.0
Veronica beccabunga					++	86	E	10.0
Carex acutiformis					++	76	E	10.0
Ranunculus sceleratus					++	65	E	10.0
Rumex hydrolopathum					++	41	E	10.0
Berula erecta					++	33	E	10.0
Carex acuta					++	24	E	10.0
Butomus umbellatus					++	23	E	10.0

++ records more than expected number - strong association
++ records 50-100% of expected number - weak association
? fewer than 5 records, so association not confirmed

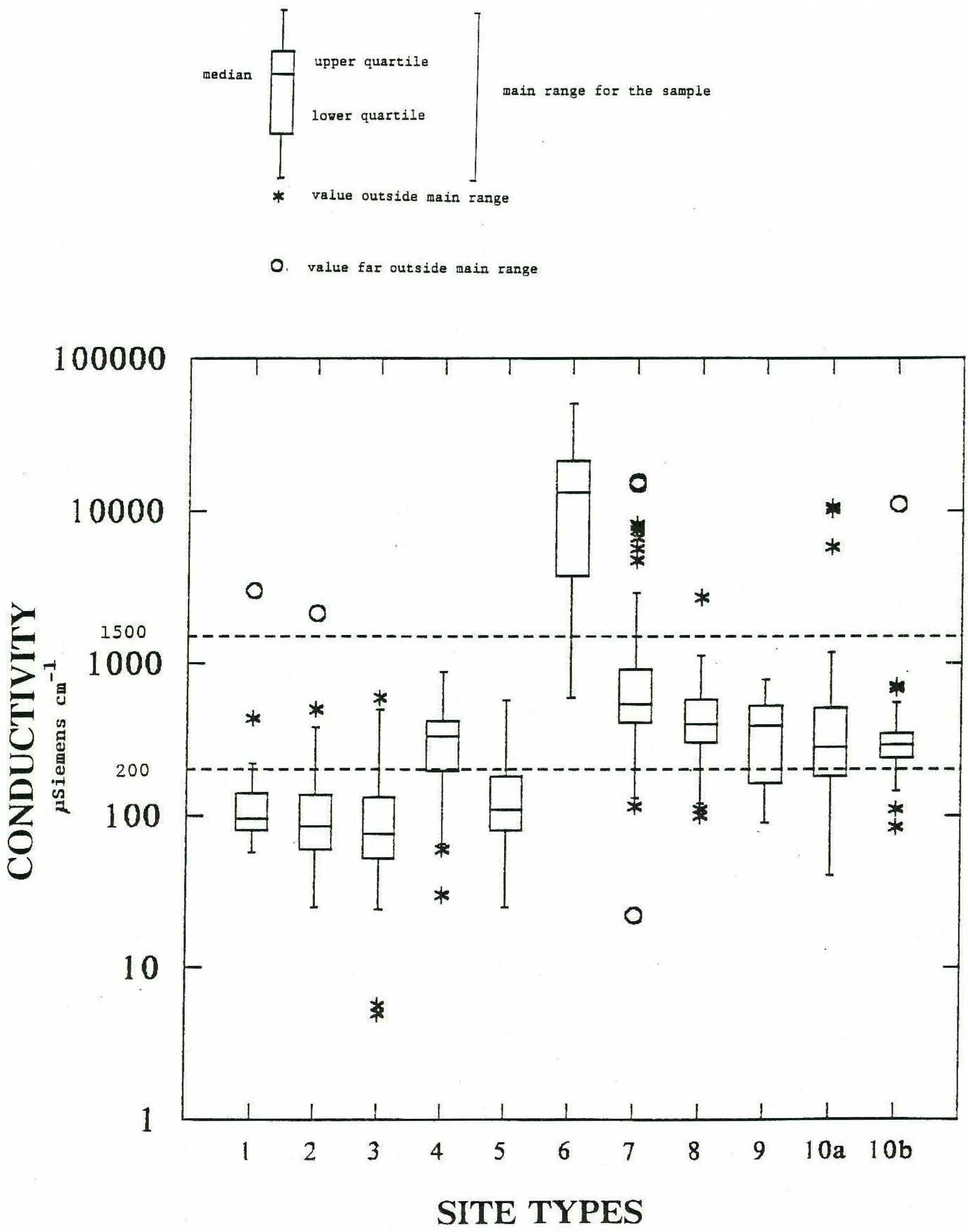
Ranges of alkalinity for site types

Values for Types 1 and 8 are not included because data are too few. Type 6 is excluded because of its salinity.

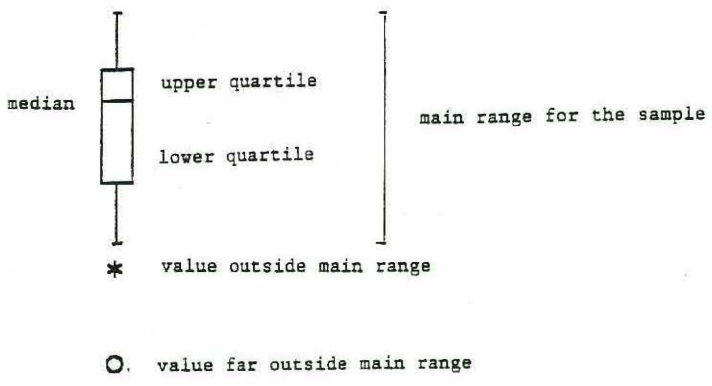


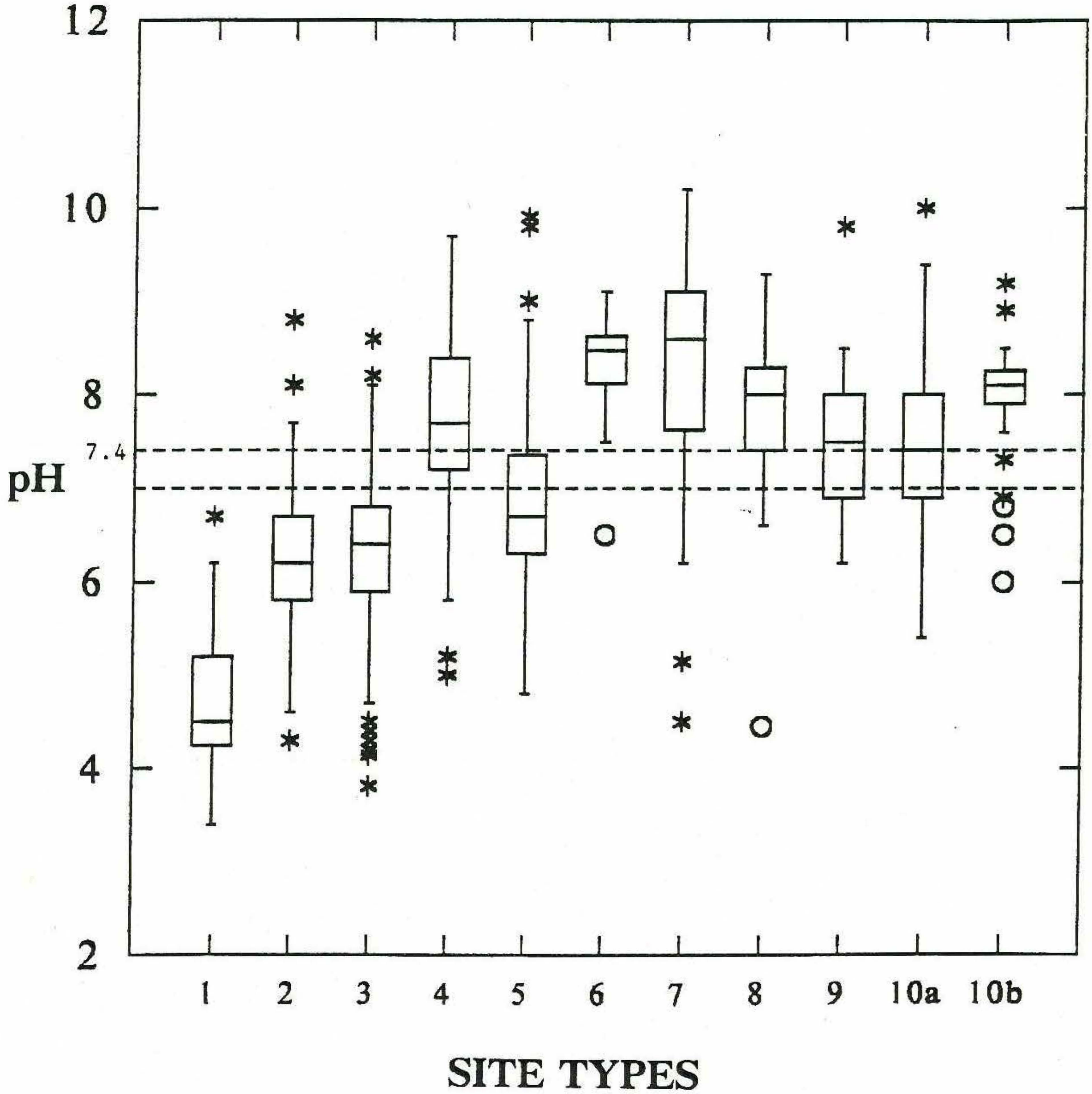


Ranges of conductivity for site types



Ranges of pH for site types





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The UK Joint Nature Conservation Committee was established by the Environmental Protection Act 1990 "for the purposes of nature conservation, and fostering the understanding thereof" in Great Britain as a whole and outside Great Britain. It is a committee of the three country agencies (the Countryside Council for Wales, English Nature and Scottish Natural Heritage), together with independent members and representatives from Northern Ireland and the Countryside Commission, and is supported by a specialist staff. JNCC and the three country agencies carry forward duties previously undertaken by the Nature Conservancy Council.

JNCC's statutory responsibilities include:

- the establishment of common scientific standards;
- the undertaking and commissioning of research;
- advising Ministers on the development and implementation of policies for or affecting nature conservation for Great Britain as a whole or nature conservation outside Great Britain;
- the provision of advice and dissemination of knowledge to any persons about nature conservation.

JNCC also has the UK responsibility for European and international matters affecting nature conservation.