JOINT NATURE CONSERVATION COMMITTEE

Plants of British standing waters: A conservation fact file

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Contents

Acknowledgements

The information in this *Fact File* has been abstracted mainly from published work, including the web sites of UK statutory nature conservation agencies.

I am indebted to Nick Stewart for supplying unpublished information on the distribution of the commoner stonewort species.

Much of the knowledge of aquatic plants that I have used in compiling this *Fact File* was gained during my employment with the Nature Conservancy Council and English Nature.

1 Introduction and scope

Aquatic plants are key ecological components of standing water systems and reflect environmental conditions. The British statutory nature conservation agencies Natural England (previously English Nature), Scottish Natural Heritage and the Countryside Council for Wales, and their fore-runner the Nature Conservancy Council, have carried out extensive surveys of aquatic vegetation, and use knowledge of plant communities to underpin nature conservation strategies for fresh waters. The same is true of the Northern Ireland Environment Agency (previously the Environment and Heritage Service). Plant assemblages and rare plants are used in the selection of statutory sites of national and international importance for wildlife, and macrophytes are also used in classifying the ecological condition of water bodies under the EC Water Framework Directive.

This *Fact File* is a compendium of information on aquatic macrophytes in England, Scotland and Wales, drawn from a wide range of sources and intended as a resource for nature conservation practitioners. Much of this information is constantly under review, especially by the statutory conservation agencies. Consolidating all this information into a single, publicly accessible computer file makes it available as a comprehensive document that can be searched, cross-checked and updated when necessary. Most of the material in this *Fact File* is taken from existing books, reports, scientific papers and web sites. It draws heavily on the *New Atlas of the British and Irish Flora* (Preston *et al.*, 2002a) and material on the Joint Nature Conservation Committee (JNCC) web site.

This *Fact File* covers macrophytes of fresh and slightly saline standing waters in Britain. These include lakes, lochs, pools, meres, brackish lagoons, reservoirs, gravel pits and ponds. Flowing water vegetation is not covered specifically, but most standing water plants also occur in rivers. The species included are submerged, floating and emergent vascular plants, a few aquatic bryophytes and all the charophytes. Aspects both of individual species and of plant communities are discussed. Check lists of native and introduced aquatic species have been drawn up and annotated with legal designations, status and distribution. An overview of vegetation classifications is given, and summaries are included of site evaluation and monitoring methods involving aquatic vegetation.

Reference is made to domestic and European legislation on nature conservation, including the Water Framework Directive.

As new plant records accumulate and as policy and legislation change, some of the information presented here will become obsolete or out of date. It is envisaged that the *Fact File* will be updated periodically, to keep abreast of these changes.

2. Native plant distribution and status

This chapter presents a check list of standing water plants, each with its conservation status. The species included are all native to Great Britain. Species status is frequently reassessed, as knowledge increases and policy evolves. The information presented here is based on status current in November 2008.

2.1 The native species check list

The check list (Table 1) covers native aquatic vascular plants, charophytes and a few fully aquatic bryophytes. The taxa listed are all at species level apart from a few subspecies of *Ranunculus*, the genus *Sphagnum* and hybrids of *Potamogeton* and *Nuphar*. The JNCC web site (www.jncc.gov.uk) gives information on the status of some other hybrids (e.g. *Carex*) and sub-species. Nomenclature follows Stace (1997) for vascular plants and Stewart (2004) for charophytes.

Numerous plant species grow on the margins of standing waters, so could be classified as either aquatic or 'wetland'. It is a matter of opinion where the line is drawn. The list of aquatic vascular plants used here is based on *Aquatic Plants in Britain and Ireland* (Preston & Croft, 1997), with the addition of a few notable species (*Cicuta virosa*, *Crassula aquatica*, *Leersia oryzoides*, *Limosella aquatica*, *Lycopodiella inundata*, *Sium latifolium* and rare hybrids of *Potamogeton*) and the omission of species exclusive to flowing waters (see Table 2). Plants of slightly saline waters are included in Table 1, but fully marine species (*Zostera* and algae) are excluded.

2.2 Status categories

These categories comprise several elements. Some are statutory, comprising species that are protected under international (EC Habitats Directive) or domestic legislation (Wildlife and Countryside Act). Some are lists of species that are threatened in Britain and are therefore Red Listed and/or designated as Biodiversity Action Plan priority species. Other categories comprise species that are not currently regarded as threatened but that have a restricted distribution (Nationally Rare, Nationally Scarce, Uncommon in England, Scotland or Wales). Numerous species qualify under more than one category. Species with blanks in all the columns do not qualify under any of the categories, so are common and widespread. The definitions of the category headings in Table 1 are given in the following paragraphs.

2.2.1 Habitats Directive (Hab. Dir.)

These species are standing water vascular plants native to the UK and listed in Annexes IIb, IVb or Vb of the EU Habitats Directive (*Directive 92/42/EEC*). The Habitats Directive requires the designation of Special Areas of Conservation (SACs) for wild plants listed on Annex IIb; strict protection (against deliberate taking, cutting, uprooting, destruction and sale) of plants listed on Annex IVb; and protection against over-exploitation of plants listed on Annex Vb. The Directive is implemented in the UK through the *Conservation (Natural Habitats, &c.) Regulations 1994*. The two British aquatic plants listed on Annex IVb of the Directive are also listed in Appendix I of the Bern Convention, which requires similar protection for these species.

Source of information
www.jncc.gov.uk

2.2.2 Schedule 8 (Sch. 8)

These are standing water vascular plant and charophyte species included in Schedule 8 of the Wildlife and Countryside Act 1981 and protected in Scotland under the Nature Conservation (Scotland) Act 2004. It is an offence intentionally to pick, uproot, destroy or sell any wild plant listed in Schedule 8. Schedule 8 is reviewed every five years.

Source of information
www.jncc.gov.uk

2.2.3 British Red Lists (Red List)

The British Red Lists comprise species that are threatened with extinction nationally. Red List categories and criteria were revised by the IUCN in 2001 (IUCN Species Survival Commission, 2001). The criteria are quantitative and cover decline in population size, geographic range or area of occupancy; small numbers of individuals; and quantitative analysis showing probability of extinction. Only one criterion need be satisfied to list a species as threatened. British plants have recently been re-evaluated using this system. Table 1 gives aquatic plants in the following threat categories:

Critically Endangered (**CR**), Endangered (**EN**), Vulnerable (**VU**).

In addition to these, the following IUCN categories are used:

Data Deficient (**DD**), Near Threatened (**NT**), Extinct (**EX**).

Data Deficient species are those for which there is inadequate information to make an assessment of the risk of extinction. Near Threatened species are without an IUCN threat designation but are close to qualifying or are likely to qualify for a threatened category in the near future. Recently extinct charophytes are included in Table 1.

Sources of information
www.jncc.gov.uk
Vascular plants: Cheffings & Farrell (2005); *Potamogeton* hybrids: Preston (1995).
Charophytes: Stewart (2004).

2.2.4 Biodiversity Action Plan priority species (UK BAP)

The 1992 *UN Convention on Biological Diversity* requires signatories to draw up national plans to conserve biodiversity. The UK Biodiversity Action Plan includes lists of priority species and habitats. Species marked **UK BAP** in Table 1 are those in the current UK priority list, produced in 2007 following a review of the original priority list (drawn up in 1994).

Sources of information
www.ukbap.org.uk

2.2.5 Nationally Rare (Nat. Rare)

Nationally Rare (**NR**) plants are species that have been recorded as native since 1986 in 15 or fewer 10 x 10 km squares in Great Britain. Those marked NR? are not listed as Nationally rare in the JNCC web site, but appear to qualify in other publications.

Sources of information
www.jncc.gov.uk

Vascular plants: *New Atlas* (Preston *et al.*, 2002a); *Potamogeton* hybrids: Preston (1995).
Charophytes: Stewart (2004).

2.2.6 Nationally Scarce (Nat. Scar.)

Nationally Scarce (**NS**) plants are species that have been recorded as native since 1986 in 16 to 100 10 x 10 km squares in Great Britain.

Sources of information
www.jncc.gov.uk

Vascular plants: *New Atlas* (Preston *et al.*, 2002a); Stewart *et al.* (1994); *Potamogeton* hybrids: Preston (1995).
Charophytes: Stewart (2004).

2.2.7 International Responsibility (Int. resp.)

Standing water vascular plants and charophytes for which Britain has International Responsibility (**IR**) are species that are endemic or near-endemic to Europe, or have a very restricted European distribution, and for which Britain has 'International Responsibility' because this country supports a high proportion (certainly or probably more than 25%) of the European population. Notable examples are *Eriocaulon aquaticum* and *Potamogeton epihydrus*, which are widespread in North America, but in Europe are restricted to the British Isles, and *Chara curta* and *C. muscosa*, which are near endemic (but *C. muscosa* may be extinct in Britain). The international status of species marked IR? is uncertain.

Sources of information
Vascular plants: Cheffings & Farrell (2005).
Charophytes: Stewart & Church (1992).

2.2.8 Biodiversity Lists for individual countries of Britain (Coun. BAP)

The Scottish Biodiversity List (required by the *Nature Conservation (Scotland) Act 2004*) and Biodiversity Lists for England and Wales (required under sections 41 and 42 of the *Natural Environment and Rural Communities Act (NERC Act) 2006*) are shown in Table 1. Standing water plant species on these lists are indicated as **E, S** and **W** in this column.

Sources of information
www.ukbap-reporting.org.uk
Biodiversity Scotland website: www.biodiversityscotland.co.uk
Wales Biodiversity Partnership website: www.biodiversitywales.org.uk

2.2.9 Uncommon in England, Scotland or Wales (Uncm. Coun)

Plants Uncommon in England (**E**)**,** Scotland (**S**) or Wales (**W**) are species that are restricted in distribution in one or more of these countries, but are not covered by higher categories of threat or restricted distribution (i.e. not Red List, UK BAP, Nationally Rare, Nationally Scarce). Uncommon species are those recorded between 1987 and 1999 from 5% or less of the 10 x10 km squares in each of the constituent countries. Qualifying numbers of 10 x 10 km squares are: England - 74 or fewer; Scotland - 55 or fewer; Wales - 14 or fewer. Species present in Scotland only as introductions from over the border are excluded from the Scottish list.

Sources of information
Vascular plants: CD-ROM provided with *New Atlas of the British and Irish Flora* (Preston *et al.*, 2002a); *Potamogeton* hybrids: Preston (1995).
Charophytes: Nick Stewart (pers com.).
Liverworts: Nick Hodgetts (pers. com.).

2.2.10 Absent from England, Scotland or Wales (Abs. Coun.)

The last column in Table 1 gives information on the distribution of species by country. The country or countries from which a species has been absent from England (**e**), Scotland (**s**) or Wales (**w**) since 1986 (or since 1969 for the rarer *Potamogeton* hybrids) are indicated. Species that are native to Britain but are present only as introductions are indicated by [ ].

Sources of information
Vascular plants: the *New Atlas* (Preston *et al.*, 2002a).
Potamogeton hybrids: Preston (1995).
Charophytes: Stewart & Church (1992); Stewart (2004); Nick Stewart (pers.com.).

Table 1 Distribution and status of native standing freshwater plants

VASCULAR PLANTS		Hab. Dir.	Sch. 8	Red List	UK BAP	Nat. Rare	Nat. Scar.	Int. resp.	Coun. BAP	Uncm. coun.	Abs coun.
Alisma gramineum	Ribbon-leaved water-plantain	-	8	CR	BAP	NR	-	-	E	-	s w
Alisma lanceolatum	Narrow-leaved water-plantain	-	-	-	-	-	-	-	-	S	-
Alisma plantago-aquatica	Water-plantain	-	-	-	-	-	-	-	-	-	-
Apium inundatum	Lesser marshwort	-	-	-	-	-	-	IR	-	-	-
Apium nodiflorum	Fool's water-cress	-	-	-	-	-	-	-	-	-	-
Baldellia ranunculoides	Lesser water-plantain	-	-	NT	-	-	-	IR	-	-	-
Berula erecta	Lesser water-parsnip	-	-	-	-	-	-	-	-	-	-
Bolboschoenus maritimus	Sea club-rush	-	-	-	-	-	-	-	-	-	-
Butomus umbellatus	Flowering rush	-	-	-	-	-	-	-	-	-	[s]
Callitriche brutia	Pedunculate water-starwort	-	-	-	-	-	-	-	-	-	-
Callitriche hamulata	Intermediate water-starwort	-	-	-	-	-	-	-	-	-	-
Callitriche hermaphroditica	Autumnal water-starwort	-	-	-	-	-	-	-	-	E W	-
Callitriche obtusangula	Blunt-fruited water-starwort	-	-	-	-	-	-	-	S	S	-
Callitriche palustris	A starwort	-	-	EN	-	NR	-	-	S	-	e w
Callitriche platycarpa	Various-leaved water-starwort	-	-	-	-	-	-	-	-	-	-
Callitriche stagnalis	Common water-starwort	-	-	-	-	-	-	-	-	-	-
Callitriche truncata	Short-leaved water-starwort	-	-	-	-	-	NS	-	-	-	s
Carex acuta	Slender-tufted sedge	-	-	-	-	-	-	-	-	S	-
Carex acutiformis	Lesser pond-sedge	-	-	-	-	-	-	-	-	-	-
Carex aquatilis	Water sedge	-	-	-	-	-	-	-	-	E W	-
Carex elata	Tufted sedge	-	-	-	-	-	-	-	S	S	-
Carex lasiocarpa	Slender sedge	-	-	-	-	-	-	-	-	E	-
Carex limosa	Mud sedge	-	-	-	-	-	-	-	-	E	-
Carex paniculata	Panicled sedge	-	-	-	-	-	-	-	-	-	-
Carex pseudocyperus	Cyperus sedge	-	-	-	-	-	-	-	-	-	[s]
Carex riparia	Great pond-sedge	-	-	-	-	-	-	-	-	S	-
Carex rostrata	Bottle sedge	-	-	-	-	-	-	-	-	-	-
Carex vesicaria	Bladder sedge	-	-	-	-	-	-	-	-	-	-

VASCULAR PLANTS		**Hab. Dir.**	**Sch. 8**	**Red List**	**UK BAP**	**Nat. Rare**	**Nat. Scar.**	**Int. resp.**	**Coun. BAP**	**Uncm. coun.**	**Abs coun.**
Catabrosa aquatica	Whorl-grass	-	-	-	-	-	-	-	-	-	-
Ceratophyllum demersum	Hornwort	-	-	-	-	-	-	-	-	S	-
Ceratophyllum submersum	Soft hornwort	-	-	-	-	-	-	-	-	W	s
Cicuta virosa	Cowbane	-	-	-	-	-	NS	-	-	-	-
Cladium mariscus	Great fen-sedge (Saw sedge)	-	-	-	-	-	-	-	-	E	-
Corrigiola litoralis	Strapwort	-	8	CR	BAP	NR	-	-	E	-	s w
Crassula aquatica	Pygmyweed	-	8	VU	-	NR	-	-	S	-	e w
Damasonium alisma	Starfruit	-	8	CR	BAP	NR	-	-	E	-	s w
Elatine hexandra	Six-stamened waterwort	-	-	-	-	-	-	?IR	-	E	-
Elatine hydropiper	Eight-stamened waterwort	-	-	-	-	-	NS	-	-	-	-
Eleocharis acicularis	Needle spike-rush	-	-	-	-	-	-	-	-	S	-
Eleocharis palustris	Common spike-rush	-	-	-	-	-	-	-	-	-	-
Eleogiton fluitans	Floating club-rush	-	-	-	-	-	-	IR	-	-	-
Eriocaulon aquaticum	Pipewort	-	-	-	-	NR	-	IR	S	-	e w
Glyceria declinata	Small reed-grass	-	-	-	-	-	-	-	-	-	-
Glyceria fluitans	Floating reed-grass	-	-	-	-	-	-	-	-	-	-
Glyceria maxima	Reed sweet-grass	-	-	-	-	-	-	-	-	-	-
Glyceria notata	Plicate sweet-grass	-	-	-	-	-	-	-	-	-	-
Groenlandia densa	Opposite-leaved pondweed	-	-	VU	-	-	-	-	-	-	[s]
Hippuris vulgaris	Mare's-tail	-	-	-	-	-	-	-	-	-	-
Hottonia palustris	Water violet	-	-	-	-	-	-	-	-	W	[s]
Hydrilla verticillata	Esthwaite waterweed	-	-	VU	-	NR	-	-	S	-	e w
Hydrocharis morsus-ranae	Frogbit	-	-	VU	-	-	-	-	-	-	[s]
Iris pseudacorus	Yellow flag	-	-	-	-	-	-	-	-	-	-
Isoetes echinospora (*setacea*)	Spring quillwort	-	-	-	-	-	-	-	-	E	-
Isoetes lacustris	Quillwort	-	-	-	-	-	-	-	-	E	-
Juncus bulbosus var. *fluitans*	Bulbous rush	-	-	-	-	-	-	-	-	-	-
Leersia oryzoides	Cut-grass	-	8	EN	BAP	NR	-	-	E	-	s w
Lemna gibba	Fat duckweed	-	-	-	-	-	-	-	-	S	-
Lemna minor	Common duckweed	-	-	-	-	-	-	-	-	-	-

VASCULAR PLANTS		**Hab. Dir.**	**Sch. 8**	**Red List**	**UK BAP**	**Nat. Rare**	**Nat. Scar.**	**Int. resp.**	**Coun. BAP**	**Uncm. coun.**	**Abs coun.**
Lemna trisulca	Ivy-leaved duckweed	-	-	-	-	-	-	-	-	-	-
Limosella aquatica	Mudwort	-	-	-	-	-	NS	-	-	-	-
Littorella uniflora	Shoreweed	-	-	-	-	-	-	IR?	-	-	-
Lobelia dortmanna	Water lobelia	-	-	-	-	-	-	-	-	E	-
Ludwigia palustris	Hampshire purslane	-	-	-	-	NR	-	-	-	-	w s
Luronium natans	Floating water-plantain	II, IV	8	-	BAP	-	NS	IR	E W	-	[s]
Lycopodiella inundata	Marsh club-moss	-	-	EN	BAP	-	NS	-	E S W	-	-
Lythrum portula	Water purslane	-	-	-	-	-	-	-	-	-	-
Menyanthes trifoliata	Bogbean	-	-	-	-	-	-	-	-	-	-
Myosotis scorpioides	Water forget-me-not	-	-	-	-	-	-	-	-	-	-
Myriophyllum alterniflorum	Alternate-flowered water-milfoil	-	-	-	-	-	-	-	-	-	-
Myriophyllum spicatum	Spiked water-milfoil	-	-	-	-	-	-	-	-	-	-
Myriophyllum verticillatum	Whorled water-milfoil	-	-	VU	-	-	-	-	-	-	s
Najas flexilis	Slender naiad	II, IV	8	-	BAP	NS	-	-	E S	-	e? w
Najas marina	Holly-leaved naiad	-	8	VU	BAP	NR	-	-	E	-	s w
Nuphar lutea	Yellow water-lily	-	-	-	-	-	-	-	-	-	-
Nuphar pumila	Least yellow water-lily	-	-	-	-	-	NS	-	-	-	w
Nuphar x *spenneriana*	*N. lutea* x *N. pumila*	-	-	-	-	NR?	-	-	-	-	-
Nymphaea alba	White water-lily	-	-	-	-	-	-	-	-	-	-
Nymphoides peltata	Fringed water-lily	-	-	-	-	-	NS	-	-	-	[s w]
Oenanthe aquatica	Fine-leaved water-dropwort	-	-	-	-	-	-	-	-	-	s
Oenanthe crocata	Hemlock water-dropwort	-	-	-	-	-	-	-	-	-	-
Oenanthe fistulosa	Tubular water-dropwort	-	-	VU	BAP	-	-	-	E S W	-	-
Oenanthe fluviatilis	River water-dropwort	-	-	-	-	-	-	IR?	-	-	s w
Persicaria amphibia	Amphibious bistort	-	-	-	-	-	-	-	-	-	-
Phalaris arundinacea	Reed canary-grass	-	-	-	-	-	-	-	-	-	-
Phragmites australis	Common reed	-	-	-	-	-	-	-	-	-	-
Pilularia globulifera	Pillwort	-	-	NT	BAP	-	NS	-	E S W	-	-
Potamogeton acutifolius	Sharp-leaved pondweed	-	-	CR	BAP	NR	-	-	E	-	s w
Potamogeton alpinus	Red pondweed	-	-	-	-	-	-	-	-	E W	-

VASCULAR PLANTS		Hab. Dir.	Sch. 8	Red List	UK BAP	Nat. Rare	Nat. Scar.	Int. resp.	Coun. BAP	Uncm. coun.	Abs coun.
Potamogeton x *bennettii*	*P. crispus* x *P. trichoides*	-	-	VU	-	NR	-	-	-	-	e w
Potamogeton berchtoldii	Small pondweed	-	-	-	-	-	-	-	-	-	-
Potamogeton x *billupsii*	*P. coloratus* x *P. gramineus*	-	-	VU	-	NR	-	-	-	-	e w
Potamogeton x *cadburyae*	*P. crispus* x *P. lucens*	-	-	EX?	-	-	-	-	-	-	e? s w
Potamogeton x *cognatus*	*P. perfoliatus* x *P. praelongus*	-	-	VU	-	NR	-	-	-	-	e? w
Potamogeton coloratus	Fen pondweed	-	-	-	-	-	NS	IR?	-	-	-
Potamogeton compressus	Grass-wrack pondweed	-	-	EN	BAP	-	NS	-	E S W	-	-
Potamogeton x *cooperi*	*P. crispus* x *P. perfoliatus*	-	-	-	-	NR	-	-	-	-	w
Potamogeton crispus	Curled pondweed	-	-	-	-	-	-	-	-	-	-
Potamogeton epihydrus	American pondweed	-	-	VU	-	NR	-	IR	S	-	[e] w
Potamogeton filiformis	Slender-leaved pondweed	-	-	-	-	-	NS	-	-	-	w
Potamogeton x *fluitans*	*P. lucens* x *P. natans*	-	-	VU	-	NR	-	-	-	-	s w
Potamogeton friesii	Flat-stalked pondweed	-	-	NT	-	-	NS	-	-	-	-
Potamogeton x *gessnacensis*	*P. natans* x *P. polygonifolius*	-	-	VU	-	NR	-	-	-	-	e
Potamogeton gramineus	Various-leaved pondweed	-	-	-	-	-	-	-	-	E W	-
Potamogeton x *griffithii*	*P. alpinus* x *P. praelongus*	-	-	-	-	NR	-	-	-	-	e s
Potamogeton x *grovesii*	*P. pusillus* x *P. trichoides*	-	-	EX?	-	-	-	-	-	-	e? s w
Potamogeton x *lanceolatifolius*	*P. gramineus x P. polygonifolius*	-	-	EX?	-	-	-	-	-	-	e s? w
Potamogeton x *lanceolatus*	*P. berchtoldii* x *P. coloratus*	-	-	EX?	-	-	-	-	-	-	e s w?
Potamogeton x *lintonii*	*P. crispus* x *P. friesii*	-	-	-	-	NR	-	-	-	-	w
Potamogeton lucens	Shining pondweed	-	-	-	-	-	-	-	-	S W	-
Potmaogeton natans	Broad-leaved pondweed	-	-	-	-	-	-	-	-	-	-
Potamogeton x *nitens*	*P. gramineus* x *P. perfoliatus*	-	-	-	-	-	-	-	-	E W	-
Potamogeton obtusifolius	Blunt-leaved pondweed	-	-	-	-	-	-	-	-	-	-
Potamogeton x *olivaceaus*	*P. alpinus* x *P. crispus*	-	-	VU	-	NR	-	-	-	-	-
Potamogeton pectinatus	Fennel-laved pondweed	-	-	-	-	-	-	-	-	-	-
Potamogeton perfoliatus	Perfoliate pondweed	-	-	-	-	-	-	-	-	-	-
Potamogeton polygonifolius	Bog pondweed	-	-	-	-	-	-	-	-	-	-
Potamogeton praelongus	Long-stalked pondweed	-	-	NT	-	-	-	-	-	-	-
Potamogeton x *prussicus*	*P. alpinus* x *P. perfoliatus*	-	-	EX?	-	-	-	-	-	-	e s? w

VASCULAR PLANTS		**Hab. Dir.**	**Sch. 8**	**Red List**	**UK BAP**	**Nat. Rare**	**Nat. Scar.**	**Int. resp.**	**Coun. BAP**	**Uncm. coun.**	**Abs coun.**
Potamogeton x *pseudofriesii*	*P. acutifolius* x *P. freisii*	-	-	EX?	-	-	-	-	-	-	e? s w
Potamogeton pusillus	Lesser pondweed	-	-	-	-	-	-	-	-	-	-
Potamogeton rutilus	Shetland pondweed	-	-	-	BAP	NR	-	IR?	S	-	e w
Potamogeton x *salicifolius*	*P. lucens* x *P. perfoliatus*	-	-	-	-	-	NS	-	-	-	-
Potamogeton x *sparganiifolius*	*P. gramineus* x *P. natans*	-	-	-	-	NR	-	-	-	-	-
Potamogeton x *sudermanicus*	*P. acutifolius* x *P. berchtoldii*	-	-	VU	-	NR	-	-	-	-	s w
Potamogeton x *suecicus*	*P. filiformis* x *P. pectinatus*	-	-	-	-	NR	-	-	-	-	w
Potamogeton trichoides	Hairlike pondweed	-	-	-	-	-	-	-	S	S W	-
Potamogeton x *undulatus*	*P. crispus* x *P. praelongus*	-	-	VU	-	NR	-	-	-	-	e s
Potamogeton x *zizii*	*P. gramineus* x *P. lucens*	-	-	-	-	-	NS	-	-	-	-
Potentilla palustris	Marsh cinquefoil	-	-	-	-	-	-	-	-	-	-
Ranunculus aquatilis	Common water-crowfoot	-	-	-	-	-	-	-	-	-	-
Ranunculus baudotii	Brackish water-crowfoot	-	-	-	-	-	-	-	-	S	-
Ranunculus circinatus	Fan-leaved water-crowfoot	-	-	-	-	-	-	-	-	S	-
Ranunculus flammula ssp. *minimus*	Lesser spearwort	-	-	DD	-	NR	-	IR	-	-	-
Ranunculus flammula ssp. *scoticus*	Lesser spearwort	-	-	DD	-	-	NS	IR	-	-	-
Ranunculus hederaceus	Ivy-leaved crowfoot	-	-	-	-	-	-	IR	-	-	-
Ranunculus omiophyllus	Round-leaved crowfoot	-	-	-	-	-	-	IR	-	-	-
Ranunculus ophioglossifolius	Adder's-tongue spearwort	-	8	VU	-	NR	-	-	-	-	s w
Ranunculus peltatus	Water crowfoot	-	-	-	-	-	-	-	-	-	-
Ranunculus penicillatus ssp. *pseudofluitans*	Stream water-crowfoot	-	-	-	-	-	-	-	-	S	-
Ranunculus reptans	Creeping spearwort	-	-	VU	-	NR	-	-	S	-	w
Ranunculus sceleratus	Celery-leaved crowfoot	-	-	-	-	-	-	-	-	-	-
Ranunculus trichophyllus	Thread-leaved water-crowfoot	-	-	-	-	-	-	-	-	-	-
Ranunculus tripartitus	Three-lobed crowfoot	-	-	EN	BAP	-	NS	-	E W	-	s
Rorippa amphibia	Great yellow-cress	-	-	-	-	-	-	-	-	W	[s]
Rorippa microphylla	Narrow-fruited water-cress		-	-	-	-	-	IR	-	-	-

VASCULAR PLANTS		**Hab. Dir.**	**Sch. 8**	**Red List**	**UK BAP**	**Nat. Rare**	**Nat. Scar.**	**Int. resp.**	**Coun. BAP**	**Uncm. coun.**	**Abs coun.**
Rumex aquaticus	Scottish dock	-	-	VU	BAP	NR	-	-	S	-	e w
Rumex hydrolapathum	Great water-dock	-	-	-	-	-	-	-	-	S	-
Ruppia cirrhosa	Spiral tasselweed	-	-	NT	-	-	NS	-	S	-	w
Ruppia maritima	Beaked tasselweed	-	-	-	-	-	-	-	-	W	-
Sagittaria sagittifolia	Arrow-head	-	-	-	-	-	-	-	-	W	[s]
Sium latifolium	Greater water-parsnip	-	-	EN	BAP	-	NS	-	E	-	s w
Sparganium angustifolium	Floating bur-reed	-	-	-	-	-	-	-	-	E	-
Sparganium natans	Least bur-reed	-	-	-	-	-	-	-	-	E W	-
Spirodela polyrhiza	Greater duckweed	-	-	-	-	-	-	-	-	-	[s]
Stratiotes aloides	Water-soldier	-	-	NT	-	NR	-	-	-	-	[s w]
Subularia aquatica	Awlwort	-	-	-	-	-	-	-	-	E W	-
Typha angustifolia	Lesser reedmace/bulrush	-	-	-	-	-	-	-	-	S	-
***Utricularia australis*	Bladderwort	-	-	-	-	-	-	-	-	-	-
Utricularia intermedia sens. lat.	Intermediate bladderwort	-	-	-	-	-	-	-	-	E W	-
**Utricularia intermedia* sens. str.	Intermediate bladderwort	-	-	DD	-	-	-	-	-	?	?
Utricularia minor	Lesser bladderwort	-	-	-	-	-	-	-	-	E	-
**Utricularia ochroleuca*	Pale bladderwort	-	-	DD	-	-	-	-	-	?	?
**Utricularia stygia*	Nordic bladderwort	-	-	DD	-	-	-	-	-	?	?
***Utricularia vulgaris* sens. lat.	Bladderwort	-	-	-	-	-	-	-	-	-	-
Veronica catenata	Pink water-speedwell	-	-	-	-	-	-	-	-	S	-
Wolffia arrhiza	Rootless duckweed	-	-	VU	-	-	NS	-	-	-	s
Zannichellia palustris	Horned pondweed	-	-	-	-	-	-	-	-	-	-

* *Utricularia intermedia* sens. lat. is a complex of species (*U. intermedia* sens. str., *U. ochroleuca*, *U. stygia*) for which there are few reliable data.
** *Utricularia vulgaris* sens. lat. comprises *Utricularia australis* and *Utricularia vulgaris* sens. str.

BRYOPHYTES		**Hab. Dir.**	**Sch. 8**	**Red List**	**UK BAP**	**Nat. Rare**	**Nat. Scar.**	**Int. resp.**	**Coun. BAP**	**Uncm. coun.**	**Abs coun.**
Fontinalis antipyretica	Willow moss	-	-	-	-	-	-	-	-	-	-
Riccia fluitans	Floating crystalwort	-	-	-	-	-	-	-	-	W	s
Ricciocarpos natans	Fringed heartwort	-	-	-	-	-	NS	-	-	-	s w
Sphagnum spp.	Bog mosses	V	(Individual species not assessed)								
CHAROPHYTES											
Chara aculeolata (*pedunculata*)	Hedgehog stonewort	-	-	-	-	-	NS	-	S	-	-
Chara aspera	Rough stonewort	-	-	-	-	-	-	-	-	E W	-
Chara baltica	Baltic stonewort	-	-	VU	BAP	NR?	-	-	E S W	-	-
Chara canescens	Bearded stonewort	-	8	EN	BAP	NR?	-	-	E S	-	w
Chara connivens	Convergent stonewort	-	-	EN	BAP	NR?	-	-	E	-	s w
Chara contraria	Opposite stonewort	-	-	-	-	-	-	-	-	E S	-
Chara curta	Lesser bearded stonewort	-	-	-	-	-	NS	IR	S W	-	-
Chara fragifera	Strawberry stonewort	-	-	VU	-	NR?	-	-	-	-	s w
Chara globularis	Fragile stonewort	-	-	-	-	-	-	-	-	S W	-
Chara hispida	Bristly stonewort	-	-	-	-	-	-	-	-	S W	-
Chara intermedia	Intermediate stonewort	-	-	EN	BAP	NR?	-	-	E	-	s w
Chara muscosa	Mossy stonewort	-	-	DD/EX?	-	-	-	IR?	-	-	e s? w
Chara rudis	Rugged stonewort	-	-	NT	-	NR?	-	-	S	-	w
Chara virgata	Delicate stonewort	-	-	-	-	-	-	-	-	-	-
Chara vulgaris	Common stonewort	-	-	-	-	-	-	-	-	-	-
Lamprothamnium papulosum	Foxtail stonewort	-	8	NT	BAP	NR?	-	-	E S	-	w
Nitella capillaris	Slimy-fruited stonewort	-	-	EX	-	-	-	-	-	-	e s w
Nitella confervacea	Least stonewort	-	-	NT	-	NR?	-	-	-	-	e w
Nitella flexilis	Smooth stonewort	-	-	-	-	-	NS	-	-	-	-
Nitella gracilis	Slender stonewort	-	-	VU	BAP	NR?	-	-	S W	-	e
Nitella hyalina	Many-branched stonewort	-	-	EX	-	-	-	-	-	-	e s w
Nitella mucronata	Pointed stonewort	-	-	-	-	-	NS	-	-	-	-
Nitella opaca	Dark stonewort	-	-	-	-	-	-	-	-	-	-

CHAROPHYTES		**Hab. Dir.**	**Sch. 8**	**Red List**	**UK BAP**	**Nat. Rare**	**Nat. Scar.**	**Int. resp.**	**Coun. BAP**	**Uncm. coun.**	**Abs coun.**
Nitella tenuissima	Dwarf stonewort	-	-	EN	BAP	NR?	-	-	E W	-	s
Nitella translucens	Translucent stonewort	-	-	-		-	-	-	-	E W	-
Nitellopsis obtusa	Starry stonewort	-	-	VU	BAP	NR?	-	-	E W	-	s? w
Tolypella glomerata	Clustered stonewort	-	-	-	-	-	NS	-	-	-	-
Tolypella intricata	Tassel stonewort	-	-	EN	BAP	NR?	-	-	E	-	s w
Tolypella nidifica	Bird's-nest stonewort	-	-	EN	BAP	NR?	-	-	S	-	e w
Tolypella prolifera	Great tassel stonewort	-	-	EN	BAP	NR?	-	-	E	-	s w

Table 2 Status of exclusively riverine or marine vascular plants

Scientific name	Common name	Habitat	Status
Apium repens	Creeping marshwort	Riparian meadows that flood; S. England	Habitats Directive, Schedule 8, Vulnerable, Nationally Rare, UK BAP, England Biodiversity List
Carex recta	Estuarine sedge	Estuaries; Scotland	Vulnerable, Nationally Rare, Scottish Biodiversity List
Limosella australis	Welsh mudwort	Estuarine; Wales (possibly introduced)	Schedule 8, Nationally Rare
Potamogeton nodosus	Loddon pondweed	Rivers; southern England	Vulnerable, Nationally Rare
Potamogeton x bottnicus	*P. pectinatus x P. vaginatus*	River Tweed	Vulnerable, Nationally Rare
Potamogeton x nericius	*P. alpinus x P. gramineus*	One river in Scotland	Taxonomy doubtful
Potamogeton x schreberi	*P. natans x P. nodosus*	Riverine; southern England	Vulnerable
Ranunculus fluitans	River water-crowfoot	Riverine; widespread	Uncommon in Scotland
Ranunculus penicillatus subsp. penicillatus	Stream water-crowfoot	Rivers in England and Wales	Nationally Scarce
Schoenoplectus triqueter	Triangular club-rush	Estuary in Devon	Schedule 8, Critically Endangered, UK BAP, England Biodiversity List
Zostera angustifolia	Narrow-leaved eelgrass	Estuaries and coasts	Possibly a variety of *Z. marina*
Zostera marina	Eelgrass	Sub-tidal	Near Threatened
Zostera noltei	Dwarf eelgrass	Estuaries and coasts	Vulnerable, Nationally Scarce

Note
A few species in Table 1 (*Crassula aquatica*, *Oenanthe fluviatilis*, *Ranunculus fluitans*, *Ranunculus penicillatus* ssp. *pseudofluitans*) are predominantly riverine but are occasionally found in standing water.

3 Introduced plants

Introduced plants may be species alien to Britain or native plants that have become established in the wild in areas of Britain outside their natural range. The definition of a non-native species (Defra, 2003) is: *A species introduced (i.e. by human action) outside its natural past or present distribution.* The aquatic vascular plants introduced to Great Britain from abroad and established in the wild here are listed in Table 3. Native British aquatic plants that have been introduced to areas of Britain well outside their natural range are listed in Table 4.

Data on the distribution and status of these plants were obtained from the *New Atlas of the British and Irish Flora* (Preston *et al.*, 2002a, including the accompanying CD ROM), *Aquatic Plants in Britain and Ireland* (Preston and Croft, 1997), the CD accompanying Hill *et al.* (2005), Stace (1997), and, for *Ludwigia* species, Defra (2007).

For alien species, Table 3 gives the date of the first record of establishment in the wild in Britain, the number of 10 x 10 km square records for 1987 onwards, and distribution by country. This information gives some indication of the rate of spread of each species. There are reports of other species (e.g. *Ludwigia hexapetala* (Defra, 2007), *Ludwigia* x *kentiana* (Clement, 2000)) in the wild, but it is not known whether they are established. The number of alien species in the wild is likely to increase. The latest addition to the alien species list is *Lemna turionifera*, which was discovered in Dorset and Lincolnshire in 2007 (Lansdown, 2008).

Crassula helmsii, *Hydrocotyle ranunculoides*, *Ludwigia peploides* (probably synonymous with *L. grandiflora* (Defra, 2007)) and *Myriophyllum aquaticum* are generally regarded as the most invasive of the newcomers, posing a current threat to native species. These species grow very vigorously and produce dense masses of vegetation, not only in the water but forming emergent carpets. *Azolla filiculoides* can also form thick, floating blankets that exclude native plants.

In November 2007 Defra issued a consultation on the revision of Schedule 9 of the Wildlife and Countryside Act 1981, as it applies to England and Wales. It is an offence to plant or otherwise cause to grow in the wild any plant listed on this Schedule. A number of aquatic plants are already listed on Schedule 9 for Scotland. These species and Defra's proposals for England and Wales are shown in Table 5. Some of these plants are not established in the wild in Britain, but are thought to pose a potential threat, especially in the face of climate change. There are proposals to prohibit the sale of most of these plants (see Table 5). [This section of the Fact File will be amended when Schedule 9 for England and Wales has been revised and the legislation amended.]

Some native plant species can be invasive, especially when naturalised outside their normal range. Examples are *Nymphoides peltata* and *Stratiotes aloides.*

Table 3 Alien aquatic vascular plants established in standing waters in Britain

Scientific name	Common name	10 km squares 1987 onwards	First record in wild in GB	Current GB distribution	Native distribution
Acorus calamus	Sweet flag	362	Before 1668	England, Scotland, Wales	Asia, Siberia, N America
Acorus gramineus	Slender sweet flag	3	1986	England	E & E Asia
Aponogeton distachyos	Cape pondweed	39	1889	England, Scotland, Wales	South Africa
***** *Azolla filiculoides*	Water fern	577	1883	England, Scotland, Wales	N & S America
Cabomba caroliniana	Carolina water-shield (Fanwort)	1	1969	England, extinct Scotland	N & S America
Calla palustris	Bog arum	20	1861	England, Scotland, Wales	Circumboreal
***** *Crassula helmsii*	New Zealand pygmyweed (Australian swamp stonecrop)	574	1956	England, Scotland, Wales	Australia & New Zealand
Egeria densa	Large-flowered water-thyme	12	c. 1950	England, Wales	S America
Elodea callitrichoides	South American waterweed	3	1948	England, extinct Wales	S America
***** *Elodea canadensis*	Canadian waterweed	1365	1842	England, Scotland, Wales	N America
***** *Elodea nuttallii*	Nuttall's waterweed	767	1966	England, Scotland, Wales	N America
***** *Hydrocotyle ranunculoides*	Floating pennywort	43	1990	England, Wales	N America
***** *Lagarosiphon major*	Curly waterweed	385	1944	England, Scotland, Wales	Southern Africa
Lemna minuta	Least duckweed	538	1977	England, Scotland, Wales	N & S America
Lemna turionifera	Red duckweed	2	2007	England	N America & northern Asia
***** *Ludwigia peploides/ grandiflora*	Water-primrose (Floating primrose-willow)	8 known sites	Post 1986	England, Wales	N & S America
***** *Myriophyllum aquaticum*	Parrot's feather (Brazilian water-milfoil)	268	1960	England, Scotland, Wales	S America
Myriophyllum heterophyllum	-	0	1941	England, extinct	N America
Myriophyllum verrucosum	-	0	1944	England, extinct	Australia
Najas graminea	-	0	1883	England, extinct	Africa, Asia, Australia
Nuphar advena	Spatter-dock	10	1963	England, Scotland	N America
Nymphaea marliacaea	A water lily	?	?	England, Scotland, Wales?	?
Pontederia cordata	Pickerelweed	32	1949	England	N & S America

Scientific name	Common name	10 km squares 1987 onwards	First record in wild in GB	Current GB distribution	Native distribution
Sagittaria latifolia	Duck potato	17	1941	England	N & S America
Sagittaria rigida	Canadian arrowhead	3	1908	England, Wales	N America
Sagittaria subulata	Narrow-leaved arrowhead	1	1962	England	N & S America
Schoenoplectus pungens	Sharp club-rush	1	1909	England	Europe, N America
Vallisneria spiralis	Tapegrass	2	1868	England	Europe, Africa, Asia, Australia

* Considered high impact species for the purposes of the Water Framework Directive in Britain (WFD-UKTAG, December 2007)

Table 4 Vascular plants restricted in their native distribution in Britain but introduced elsewhere in the country

Introduced to England from Scotland	
Potamogeton epihydrus	American pondweed (native to Scotland)
Introduced to Scotland	
Butomus umbellatus	Flowering rush
Carex pseudocyperus	Cyperus sedge
**Groenlandia densa*	Opposite-leaved pondweed
Hottonia palustris	Water violet
Hydrocharis morsus-ranae	Frogbit
Luronium natans	Floating water-plantain
Nymphoides peltata	Fringed water-lily
Rorippa amphibia	Yellow-cress
Sagittaria sagittifolia	Arrow-head
Stratiotes aloides	Water-soldier
The above species have been recorded in Scotland since 1986. *Spirodela polyrhiza* (Greater Duckweed) was introduced to Scotland but appears to be extinct. *Recorded as a native before 1970, but a recent record is believed to be an introduction.	
Introduced to Wales	
Nymphoides peltata	Fringed water-lily
Stratiotes aloides	Water-soldier

Native in parts of England but widely introduced in other parts of this country		
Ludwigia palustris	Hampshire purslane	Native to Dorset, Hampshire and (previously) Sussex. Introduced in a few places elsewhere.
Luronium natans	Floating water-plantain	Natural distribution Wales, West Midlands, North West England. Introduced in Norfolk.
Nymphoides peltata	Fringed water-lily	Native to Thames valley and East Anglia. Introduced very widely elsewhere.
Stratiotes aloides	Water soldier	Native to eastern England. Introduced widely elsewhere.

Table 5 Plants listed on Schedule 9 for Scotland and proposed by Defra in 2007 for listing in England and Wales

Scientific name	Common name	Sch 9 Scot	Prop. Sch 9 Eng & Wal	Estab. in the wild	Proposed sale ban
Azolla filiculoides	Water fern	Yes	Yes	Yes	Yes
Cabomba caroliniana	Carolina water-shield	Yes	Yes	Yes	No
Crassula helmsii	New Zealand pygmyweed	Yes	Yes	Yes	Yes
Eichhornia crassipes	Water hyacinth	Yes	Yes	No	Yes
Elodea spp.	Pondweeds	No	Yes	Yes	Yes
Hydrocotyle ranunculoides	Floating pennywort	Yes	Yes	Yes	Yes
Lagarosiphon major	Curly waterweed	Yes	Yes	Yes	Yes
Ludwigia grandiflora	Water primrose	Yes	Yes	Yes?	Yes
Ludwigia peploides	Floating primrose willow	Yes	Yes	Yes	Yes
Myriophyllum aquaticum	Parrot's feather	Yes	Yes	Yes	Yes
Pistia stratiotes	Water lettuce	Yes	Yes	No	No
Sagittaria latifolia	Duck potato	No	Yes	Yes	No
Salvinia molesta	Giant salvinia	Yes	Yes	No	No

4 Aquatic vegetation communities and habitat classifications

Site classifications are essential for conservation purposes, including inter-site quality assessments, in which it is important to compare like with like. Vegetation is frequently used in the classification process. (For Water Framework Directive typology, see Section 8.)

4.1 National Vegetation Communities

The National Vegetation Communities (NVC) classification (Rodwell, 1995) recognises 24 aquatic communities (two of which are associated with flowing waters) and 23 swamp/water-margin communities. There are also five tall-herb fen communities, which can occur in habitats closely associated with standing and flowing waters. The aquatic communities, along with a summary description of their habitats and distribution, are listed in Table 6. NVC swamp and tall-herb fen communities are listed in Table 7.

4.2 JNCC botanical classifications of lakes

Since the late 1970s, the British conservation agencies have carried out large numbers of macrophyte surveys of lakes and other standing fresh waters. The pH and conductivity of the water have been measured at most of these sites and a smaller number of alkalinity measurements have been made.

An initial vegetation classification of British standing waters (Palmer, 1989; Palmer *et al.*, 1992) was produced, using a TWINSPAN analysis (Hill, 1979) of survey data from 1,124 lakes, lochs, meres, pools, brackish lagoons, gravel pits, reservoirs, ponds and canals throughout England, Scotland and Wales. The plants included in the analysis were submerged and floating species; emergent plants were excluded. Ten site types (1 to 10) were recognised.

The GB Standing Waters database, now held by the Joint Nature Conservation Committee, was subsequently expanded to incorporate botanical survey data from a total of 3,447 sites. The dataset is heavily biased towards Scotland because about 3,000 of the sites are north of the border. A TWINSPAN analysis was carried out on the expanded dataset, but this time canals were excluded. The resulting classification (Duigan *et al.*, 2006, 2007) is based on data for 100 submerged and floating taxa, seven of which (*Chara* spp., *Nitella* spp., *Riccia fluitans*, *Fontinalis antipyretica*, *Sphagnum* spp., *Enteromorpha* spp. and fucoid algae) are non-vascular plants.

Eleven distinct lake groups, A to J (including two sub-groups of C), were recognised. The second classification is broadly similar to the first. Both represent a continuum of standing water types, the series strongly related to alkalinity, pH, conductivity and geographical location. Group A contains the most strongly acid and most nutrient-poor waters, mostly situated in the uplands. Broadly, there is a progression of increasing pH, alkalinity and conductivity through the groups from A to I. Group I is made up of highly calcareous lowland sites. Group J stands out from the series, as it

consists of slightly saline water bodies. A summary description of the lake groups in the second classification, taken from Duigan *et al.* (2006, 2007), is given as Table 8.

Duigan *et al.* (2006) is available on the JNCC web site. It contains a detailed account of the classification and a list of all the sites surveyed.

Table 6 National Vegetation Classification aquatic communities

NVC community		Typical habitat	Distribution in Britain
A1	*Lemna gibba*	Still/sluggish, eutrophic, base-rich water	South-eastern England, south Wales
A2	*Lemna minor*	Still/slow-moving, meso- to eutrophic water	Throughout lowland Britain
A3	*Spriodela polyrhiza-Hydrocharis morsus-ranae*	Unpolluted, meso- to eutrophic standing water	South & east England, southern Wales
A4	*Hydrocharis morsus-ranae-Stratiotes aloides*	Mesotrophic, calcareous standing water	Very local; mainly Norfolk Broadlands
A5	*Ceratophyllum demersum*	Still/slow-moving, eutrophic water	Mainly south-eastern lowlands
A6	*Ceratophyllum submersum*	Still/slow-moving, eutrophic water, usually brackish	Coastal SE England; scattered in west
A7	*Nymphaeae alba*	Still/slow-moving, water, especially base-poor & peaty	Throughout; common in north & west
A8	*Nuphar lutea*	Still/slow-moving, meso- to eutrophic water	Mainly lowlands of southern Britain
A9	*Potamogeton natans*	Still/flowing, meso- to oligotrophic (eutrophic) water	Throughout Britain
A10	*Polygonum amphibium* [*Persicaria amphibia*]	Still/slow-moving, moderately nutrient-rich water	Most of lowlands and upland fringes
A11	*Potamogeton pectinatus-Myriophyllum spicatum*	Still/flowing, meso- to eutrophic, sometimes brackish	Lowlands, mainly in England
A12	*Potamogeton pectinatus*	Still/flowing, eutrophic, often polluted waters	Mainly lowlands of southern Britain
A13	*Potamogeton perfoliatus-Myriophyllum alterniflorum*	Still/slow-moving, mesotrophic, base-poor water	Mainly north & west Britain
A14	*Myriophyllum alterniflorum*	Still/flowing, oligotrophic, base-poor water	Mainly upland fringes of north & west
A15	*Elodea canadensis*	Still/sluggish, eutrophic water	Widespread in lowlands
A16	*Callitriche stagnalis*	Still/flowing, shallow, eutrophic to oligotrophic water	Throughout lowlands and in mountains
A17	*Ranunculs penicillatus* ssp *pseudofluitans*	Flowing, base-rich, usually mesotrophic water	Lowland England, Wales, S Scotland
A18	*Ranunculus fluitans*	Larger flowing waters, usually mesotrophic	Mainly northern & central England
A19	*Ranunculus aquatilis*	Still/flowing meso- to eutrophic water	Lowlands and upland fringes
A20	*Ranunculus peltatus*	Still/flowing meso- to eutrophic water	Lowlands and upland fringes
A21	*Ranunculus baudotii*	Still/slow-moving, brackish water	Coastal; commoner in southern Britain
A22	*Littorella uniflora-Lobelia dortmanna*	Clear, stony, oligotrophic standing water	Mainly northern & western Britain
A23	*Isoetes lacustris/setacea*	Deep, clear, stony, oligotrophic standing water	Mainly northern & western Britain
A24	*Juncus bulbosus*	Shallow, base-poor, oligotrophic water, often peaty	Mainly northern & western Britain

Table 7 National Vegetation Classification swamp and tall-herb fen communities

Swamp communities	
S1	*Carex elata* swamp
S2	*Cladium mariscus* swamp and sedge-beds
S3	*Carex paniculata* swamp
S4	*Phragmites australis* swamp and reed-beds
S5	*Glyceria maxima* swamp
S6	*Carex riparia* swamp
S7	*Carex acutiformis* swamp
S8	*Schoenoplectus lacustris* swamp
S9	*Carex rostrata* swamp
S10	*Equisetum fluviatile* swamp
S11	*Carex vesicaria* swamp
S12	*Typha latifolia* swamp
S13	*Typha angustifolia* swamp
S14	*Sparganium erectum* swamp
S15	*Acorus calamus* swamp
S16	*Sagittaria sagittifolia* swamp
S17	*Carex pseudocyperus* swamp
S18	*Carex otrubae* swamp
S19	*Eleocharis palustris* swamp
S20	*Schoenoplectus tabernaemontani* swamp
S21	*Scirpus maritimus* swamp
S22	*Glyceria fluitans* water-margin vegetation
S23	Other water-margin vegetation *(Glycerio-Sparganion)*
Tall-herb fen communities	
S24	*Phragmites australis-Peucedanum palustre* tall-herb fen
S25	*Phragmites australis-Eupatorium cannabinum* tall-herb fen
S26	*Phragmites australis-Urtica dioica* tall-herb fen
S27	*Carex rostrata-Potentilla palustris* tall-herb fen
S28	*Phalaris arundinacea* tall-herb fen

Table 8 Vegetation communities of British lakes (2006 classification)

Lake group	Ecological description
A	Small, predominantly northern dystrophic peat or heathland pools, dominated by *Sphagnum* spp.; highly acidic water, low conductivity and very low alkalinity.
B	Widespread, usually low-lying acid moorland or heathland pools and small lakes, with a limited range of plants, especially *Juncus bulbosus*, *Potamogeton polygonifolius* and *Sphagnum* spp.; acidic water with low conductivity and alkalinity.
C1	Northern, usually small to medium-sized, acid, largely mountain lakes, with a limited range of plants, but *Juncus bulbosus* and *Sparganium angustifolium* constant; water acidic, with low conductivity and very low alkalinity; some lakes with very clear water.
C2	North western, predominantly large, slightly acid, upland lakes, supporting a diversity of plant species, *Juncus bulbosus* constant, often with *Littorella uniflora* and *Lobelia dortmanna*, in association with *Myriophyllum alterniflorum;* water brown or clear, generally acidic but significantly less acidic than C1, low conductivity and alkalinity.
D	Widespread, often large, mid-altitude circumneutral lakes, with a high diversity of plants, including *Littorella uniflora*, *Myriophyllum alterniflorum*, *Callitriche hamulata*, *Fontinalis antipyretica* and *Glyceria fluitans*; water weakly acidic, with low conductivity and moderate alkalinity.
E	Northern, often large, low altitude and coastal, above-neutral lakes with high diversity of plant species, including *Littorella uniflora*, *Myriophyllum alterniflorum*, *Potamogeton perfoliatus* and *Chara* spp.; water pH circumneutral and above, conductivity and alkalinity moderately high.
F	Widespread, usually medium-sized, lowland, above neutral lakes, with a limited range of species, but typified by water-lilies and other floating-leaved vegetation The water usually has above neutral pH, moderate conductivity and high alkalinity.
G	Central and eastern, above neutral, lowland lakes, with *Lemna minor*, *Elodea canadensis*, *Potamogeton natans* and *Persicaria amphibia;* water circumneutral pH, moderate conductivity and high alkalinity.
H	Northern, small, circumneutral, lowland lakes, with low species diversity characterised by the presence of *Glyceria fluitans* and *Callitriche stagnalis*; water circumneutral pH, moderate conductivity and high alkalinity.
I	Widespread, mostly moderately large, base-rich lowland lakes, with *Chara* spp., *Myriophyllum spicatum* and a diversity of *Potamogeton* species; water relatively high pH, moderate conductivity and high alkalinity.
J	Northern coastal, brackish lakes, with *Potamogeton pectinatus*, *Enteromorpha* spp., *Ruppia maritima* and fucoid algae; water brackish, high pH, conductivity and alkalinity.

4.3 Classification of ditch systems

Numerous vegetation surveys of grazing marsh ditch systems have been carried out by the conservation agencies and classifications have been produced for geographically restricted areas (e.g. Doarks & Leach, 1990). Despite this, ditch systems lack a detailed national vegetation classification comparable with that for lakes. The classification used for the selection of SSSIs (Nature Conservancy Council, 1989) is very simple and is summarised in Table 9.

Table 9 Classification of ditch vegetation types

I.	**Freshwater ditches**	
IA	Open water present; emergent plants absent or forming fringes occupying up to 70% of the width of the watercourse	
	IAa	Watercourses with a low cover (less than about 30%) of Lemnaceae and/or *Azolla filiculoides*
	IAb	Watercourses with a moderate or high cover (over about 30%) of Lemnaceae and/or *Azolla filiculoides*
	IAc	Watercourses with few or no higher plants (filamentous algae and/or *Enteromorpha* present and often abundant)
IB	Emergent plants dominant, filling over 70% of the watercourse; submerged plants scarce or absent. Main vegetation types:	
	IBa	*Phragmites australis*
	IBb	*Glyceria maxima*
	IBc	Floating mats of small grasses
	IBd	Other species
II	**Brackish ditches**	
IIA	Open water present; emergent plants absent or forming fringes occupying up to 70% of the width of the watercourse	
	IIAa	Higher plants dominant
	IIAb	Very few or no higher plants (algae present and often abundant)
IIB	Emergent plants dominant, filling over 70% of the watercourse; submerged plants scarce or absent. Main vegetation types:	
	IIBa	*Phragmites australis*
	IIBb	*Scirpus maritimus*
	IIBc	Other species

4.4 The Habitats Directive

Annex I of the Habitats Directive (*Directive 92/42/EEC*) specifies natural habitat types of interest in Europe. These are habitats in danger of disappearance (priority habitats) or which have a small natural range or present outstanding examples of typical characteristics of biogeographical regions. They form a sub-set of the EUNIS (European Nature Information Service) typology of habitats produced by the European Environment Agency (available at http://eunis.eea.eu.int/habitats.jsp). The Habitats Directive requires the designation of Special Areas of Conservation (SACs) for habitats listed in Annex I. The Annex I freshwater and brackish water habitats that occur in the UK (Brown *et al.*, 1997; Jackson & McLeod, 2000) are as follows. Those marked * are priority habitats.

- Oligotrophic waters containing very few minerals of Atlantic sandy plains *(Littorelletalia uniflorae);*
- Oligotrophic to mesotrophic waters with vegetation of the *Littorelletea uniflorae* and/or the *Isoëto-Nanojuncetea;*
- Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp.;

- Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation;
- Natural dystrophic lakes and ponds;
- * Mediterranean temporary ponds;
- * Turloughs;
- Watercourses of plain to montane levels with *Ranunculion fluitantis* and *Callitricho-Batrachian* vegetation;
- * Coastal lagoons.

Duigan *et al.* (2006, 2007) give a table showing the relationship between the current British lakes classification and Habitats Directive Annex I habitat types (Table 10).

Table 10 The relationship between British lake groups and habitats protected under the Habitats Directive

Annex I habitat types	A	B	C1	C2	D	E	F	G	H	I	J
Natural dystrophic lakes	XX	X	X	X							
Oligotrophic waters of sandy plains etc.		XX		XX							
Oligotrophic to mesotrophic waters etc.		X	XX	XX	XX	XX					
Hard oligo-mesotrophic waters with *Chara* spp.		X		X		XX	XX	X		XX	
Natural eutrophic lakes						XX		XX		XX	
Coastal lagoons						X					XX

A to J = British lake groups
X = weak association between Annex I habitat type and lake group
XX = strong association between Annex I habitat type and lake group

4.5 UK Biodiversity Action Plan priority habitats

The UK Biodiversity Action Plan includes a list of priority habitats, which was revised in 2007 (see www.ukbap.org.uk). The freshwater habitats in this list are:

- Oligotrophic and dystrophic lakes (added in the 2007 review);
- Mesotrophic lakes;
- Eutrophic standing waters;
- Aquifer-fed naturally fluctuating water bodies;
- Ponds (added in the 2007 review);
- Rivers (added in the 2007 review and now includes the previous priority habitat: Chalk rivers).

4.6 Attribute-based classification of aquatic plants

Willby *et al.* (2000) classified 120 European hydrophytes into attribute groups based on 17 intrinsic morphological and life history traits. Twenty attribute groups were recognised, some of them conventional life forms (utricularids, isoetids, hydrocharids and lemnids). A highly significant correlation between traits and habitat use was demonstrated, including a trade-off between resistance-type traits (related to streamlining, flexibility and anchorage) in riverine and littoral habitats, and resilience-type traits (e.g. turions, small body size and free-floating growth form) in rarely disturbed habitats. Another feature recognised was a shift from high investment, competitive traits and low reproductive output in deep, stable habitats, to ruderal and desiccation resistance traits in shallow, fluctuating habitats.

5 Site evaluation

5.1 SSSI selection guidelines

The nature conservation agencies have a duty under the *Wildlife and Countryside Act 1981*, as amended, to notify any area of land which in their opinion is 'of special interest by reason of any of its flora, fauna, or geological or physiographical features' (Sites of Special Scientific Interest - SSSIs).

In 1989 the Nature Conservancy Council published *Guidelines for Selection of Biological SSSIs*, which superseded internal guidance on selecting SSSIs, originally issued in 1979 and revised in 1983. The *Guidelines* are based on principles laid down by Ratcliffe (1977). Since 1991, the Joint Nature Conservation Committee has revised parts of the 1989 *Guidelines* (see www.jncc.gov.uk), but not the sections on vascular plants, lakes and ditch systems.

The *Guidelines* lay down a rationale for site evaluation, based on both species groups and habitats, and specifies minimum standards for SSSIs. For species, assessments of threat and rarity are required (see Table 1 for current species status). For habitats, a classification is needed, in order to compare like with like. SSSI selection takes place within specified areas of search (AOS).

5.2 Vascular plant species: SSSI selection

In the 1989 *Guidelines*, SSSIs are selected for vascular plant species using the following criteria:

- All sites with viable populations of species listed on Schedule 8 of the Wildlife and Countryside Act 1981.
- Sites with one Red Data Book [Red List] species if it has:
    - ◊ the largest population in Britain;
    - ◊ a good population on a site that is a good example of a habitat type that has not been already been chosen;
    - ◊ a good population in an AOS supporting a substantial proportion of localities for the species;
    - ◊ a good population on the edge of the species' range;
    - ◊ the only occurrence of the species in the AOS.
- All sites with high scoring combinations of species (i.e. a score of 200 or more) qualify. The score is the sum of the individual scores for species present on the site. The following scores are used:
    - o Species listed on Schedule 8 score 200;
    - o Species occurring in 15 or fewer 10x10 km squares (other than Schedule 8 species) score 100;
    - o Species occurring in 16 to 100 10x10 km squares (Nationally Scarce) score 50.

- Sites with endemic species – the largest population in the AOS.
- Sites with non-endemic species threatened in Europe – the best native population in the AOS.
- Sites with declining species (not in the Red List or Nationally Scarce categories), species at the edge of their range or with populations that are phenotypically distinct from the prevailing form.
- Regionally rare species.
- Sites with 75% or more of the total vascular plant species list for an NVC community type.
- Microspecies and regularly occurring hybrids should be represented in at least one SSSI in Britain.

5.3 Non-vascular plants: SSSI selection

Guidelines for the selection of SSSIs for non-vascular plants were revised in 1992 (Hodgetts, 1992). The only non-vascular plants likely to be used in SSSI selection for standing waters are the charophytes. The relevant criteria for this group are:

- Schedule 8 species - criteria identical to those for vascular plants.
- Red List plants - criteria identical to those for vascular plants.
- Combinations of species - species scores are the same but the qualifying site score is 300 (rather than 200) in south-west England, parts of North Wales, the Lake District and much of Scotland.
- Sites with large populations of declining species (not in the Red List or Nationally Scarce categories), species at the edge of their range or with populations that are phenotypically distinct from the prevailing form.

5.4 Lake habitats: SSSI selection

The lakes section of the 1989 *Guidelines* is based on the original JNCC classification of lakes (Palmer, 1989) and on the NVC swamp/tall-herb fen classification. The principles are, however, applicable to the new lakes classification (Duigan *et al.*, 2006, 2007). The criteria used to select lakes and canals within each AOS can be summarised as follows:

- Each open water type present should be represented by at least one site.
- Sites with eight or more *Potamogeton* species qualify for consideration, as long as at least one of these species is Nationally Scarce or locally rare.
- Other factors that should be considered in selecting the ‘best’ sites are:

    ◊ species-richness of aquatics;
    ◊ numbers of NVC swamp communities represented;
    ◊ extent of reed swamp;
    ◊ diversity of physical features;
    ◊ altitudinal spread of lake types;

- ◊ good representation of nationally rare lake types (e.g. mesotrophic, brackish, marl, arctic-alpine and naturally fluctuating waters);
- ◊ good representation of site types that are locally uncommon;
- ◊ naturalness - absence of artificial physical features, pollution and introduced species;
- ◊ palaeolimnological and geological features;
- ◊ position in an ecological series (e.g. the transition from fresh to saline water);
- ◊ size of the water body;
- ◊ naturalness of the catchment.

5.5 Special Areas of Conservation (SACs)

Special Areas of Conservation (SACs) have been designated throughout the UK for good examples of all 78 Habitats Directive Annex I habitats that occur in the country (see Section 4.4 for the standing water habitat types) and all 43 native Annex II species. The only British freshwater plant species included in Annex II are Slender naiad *Najas flexilis* and Floating water-plantain *Luronium natans.*

Many SSSIs are also designated as SACs. The Natura 2000 site series comprises SACs and Special Protection Areas (SPAs) designated under the 1979 Birds Directive. Selection principles used for SACs (Brown *et al.,* 1997), are:

- **Habitats**
  - ◊ Representativity
  - ◊ Area of habitat
  - ◊ Conservation of structure and function
- **Species**
  - ◊ Proportion of UK population
  - ◊ Conservation of features important for species survival
  - ◊ Isolation of species populations
- **General**
  - ◊ Priority/non-priority status
  - ◊ Rarity
  - ◊ Geographical range
  - ◊ Special UK responsibilities
  - ◊ Multiple interest

5.6 Ramsar sites

Sites designated under the 1971 Ramsar Convention on Wetlands (www.ramsar.org, 2004) are selected because of their international significance in terms of ecology, botany, zoology, limnology or hydrology. Ramsar sites form a global network of freshwater and marine habitats. In August 2007 there were 127 designated or proposed Ramsar sites in Britain (and 19 in Northern Ireland), some of which comprise or include lakes. A lake may qualify as a Ramsar site under ornithological criteria, for fish populations or under one or more of the following general criteria, some of which are relevant to macrophyte vegetation:

- It is a representative, rare or unique example of a natural or near-natural lake type.
- It supports vulnerable, endangered, or critically endangered species or communities.
- It supports populations of species important for biological diversity.
- It supports species at a critical stage in the life cycles or provides refuge under adverse conditions.

5.7 Lake Assessment for Conservation (LACON)

Work is in progress to produce LACON - Lake Assessment for Conservation (Palmer, in prep.). This is a semi-quantitative method of assessing the nature conservation interest of standing waters in Great Britain. It is modelled on SERCON - System for Evaluating Rivers for Conservation (Boon *et al.*, 1997).

LACON is based on the most important and well-used of the 'classic' nature conservation evaluation criteria (naturalness, representativeness (typicalness), rarity and diversity). LACON elaborates this approach by using a range of attributes under each criterion and applying a scoring system to achieve rigour and repeatability in the assessment. Thus, the value of a site for a particular criterion is quantified in relation to that of other sites. LACON also attempts to quantify the impact of human activity on a water body.

Initially at least, LACON will rely heavily on botanical data. A comprehensive 'library' of reference data on which the scoring is based (including some of the information included in this *Fact File*) is incorporated in the LACON manual. Automation of the scoring system is planned.

5.8 The Predictive System for Multimetrics (PSYM)

PSYM has been developed by the Environment Agency and the Ponds Conservation Trust for assessing the biological quality of still waters (Williams *et al.*, 1998). It is based on survey data from 300 ponds and small lakes in England and Wales, covering a wide range of altitudes, land types and degrees of site impairment. PSYM combines a predictive approach with a multimetric-based method for ecological quality assessment, to indicate the extent of departure from reference (unimpaired) condition.

The PSYM computer programme calculates metrics for macrophytes and invertebrates, using biological survey data and simple environmental data (e.g. altitude, geology, area, pH, shade) to predict scores for the site. An Ecological Quality Index (EQI) for each metric is produced by dividing the observed by the expected scores. EQI is transformed to a four-point (0-3) scale or Index of Biotic Integrity (IBI). Finally, IBIs for all the metrics are summed to give an overall IBI, expressed as a percentage of the maximum possible score, which represents unimpaired condition.

5.9 Important Plant Areas (IPAs)

An Important Plant Area (IPA) (Palmer & Smart, 2001) is a non-statutory site of exceptionally high botanical value in an international context. A list of IPAs identified in the UK is available at www.plantlife.org.uk. Stewart (2004) gives details of UK IPAs for stoneworts. Criteria for selecting IPSs are:

A. The site holds significant populations of one or more species that are of global or European conservation concern.
B. The site has an exceptionally rich flora in a European context in relation to its biogeographic zone.
C. The site is an outstanding example of a habitat type of global or European plant conservation and botanical importance.

5.10 Ditch systems: SSSI selection

In the *Guidelines for Selection of Biological SSSIs*, selection of ditch systems is based on the simple vegetation classification shown in Table 9 (Section 4.3). Standards for assessing the relative species-richness of the vegetation, based on the number of aquatic and wet bank species per 20 m length of ditch, are given as follows:

Freshwater systems	**Brackish systems**
Exceptional – 15 or more species	Exceptional – 10 or more species
Good – 10 to 14 species	Good – 6 to 9 species
Fair – 6 to 9 species	Fair/poor – 5 or fewer species
Poor – 5 or fewer species	

The following guidance is given for site selection:

- The complete range of ditch vegetation types (apart from species-poor types such as those dominated by algae) should be covered.
- There should be good representation of rarer ditch types (mesotrophic and brackish) where they are present.
- There should be an emphasis on species richness. The mean number of plant species per 20 m length in a freshwater system should be 10 or more or at least 50% of wet ditches in the system should rate as good or exceptional.
- The extent of the ditch system should be taken into account. A short length (1 to 5 km) must be very species-rich or support rare species to qualify.
- Surrounding land use should be taken into consideration.

5.11 Ditch systems: 'Buglife' evaluation scheme

A system for evaluating and ranking the nature conservation interest of the plant and invertebrate assemblages of ditches in England and Wales has been produced by Buglife – The Invertebrate Conservation Trust (Palmer, Drake & Stewart, 2008).

A checklist of ditch macrophytes is included. Four metrics for indicating the nature conservation value of the plant assemblages are provided. These scores are for:

- Species Richness: number of native aquatic species (based on checklist);
- Conservation Status: sum of species rarity scores;
- Habitat Quality: number of species indicative of good water quality;
- Community Naturalness: sum of ‘threat’ scores for introduced species.

These metrics can be applied to species lists from either whole ditch complexes or ditch lengths; they can be used both to rank areas for purposes such as SSSI selection and to identify the highest or lowest quality ditches within a site. The scores can be analysed in relation to ditch management or water quality, as an aid to future management. The system could also be used to monitor change in the quality of ditch biota over time.

6 Monitoring

6.1 Common Standards Monitoring (CSM)

Common Standards Monitoring (CSM) is a rapid, simple assessment of the condition of features in protected sites, including SACs and SSSIs (see www.jncc.org.uk). Features are the species and habitats for which the sites were designated. CSM enables a feature to be assessed as *Favourable*, *Unfavourable* or *Destroyed* (*partially or completely*).

For each feature, a small number of characteristics (attributes) are chosen that describe its condition. Attributes are quantifiable and measurable. Favourable condition is defined by setting broad targets for each attribute of the feature. Condition assessments are based on field survey but may utilise other information (e.g. aerial photographs). They provide a guide for site management.

Common Standards Monitoring Guidance for Standing Waters (Joint Nature Conservation Committee, 2005) covers the following features (lake types):

- Oligotrophic waters containing very few minerals of Atlantic sandy plains *(Littorelletalia uniflorae)*;
- Oligotrophic to mesotrophic waters with vegetation of the *Littorelletea uniflorae* and/or the *Isoëto-Nanojuncetea*;
- Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp.;
- Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation;
- Natural dystrophic lakes and ponds;
- Turloughs and Breckland Meres (temporary lakes principally filled by subterranean waters).

The attributes and targets used to assess the condition of lakes, together with the methods of assessment, are described in detail in the CSM guidance (Joint Nature Conservation Committee, 2005). The following is a summary of the targets for each of the attributes:

- Extent - no loss of extent of standing water.
- Vegetation composition: macrophyte community composition - characteristic species present (see Table 11).
- Vegetation composition: negative indicator species - non-native species absent or at low levels; non-charophyte algal dominance low.
- Macrophyte community structure - characteristic vegetation zones present; maximum depth distribution and structure maintained.
- Water quality - stable and appropriate nutrient levels and pH/ANC; oxygen levels adequate; no excessive growths of cyanobacteria or green algae.
- Hydrology - natural regime.
- Substrate - natural shoreline; natural and characteristic substrate.
- Sediment load - maintained as natural.
- Indicators of local distinctiveness - distinctive elements (e.g. rare plants, invertebrates, habitat features) maintained.

Table 11 Characteristic macrophytes of standing water features

Feature (lake type)	Characteristic species	
Oligotrophic waters containing very few minerals of Atlantic sandy plains *(Littorelletalia uniflorae)*	*Littorella uniflora* *Isoetes lacustris* *Isoetes echinospora* *Lobelia dortmanna* *Eleogiton fluitans*	*Elatine hexandra* *Pilularia globulifera* *Myriophyllum alterniflorum* *Apium inundatum*
Oligotrophic to mesotrophic waters with vegetation of the *Littorelletea uniflorae* and/or the *Isoëto-Nanojuncetea*	*Littorella uniflora* *Isoetes lacustris* *Isoetes echinospora* *Lobelia dortmanna* *Subularia aquatica* *Sparganium angustifolium* *Luronium natans* *Potamogeton rutilus* *Pilularia globulifera* *Elatine hexandra* *Baldellia ranunculoides* *Carex rostrata* *Utricularia spp.*	Mesotrophic waters only: *Potamogeton alpinus* *P. praelongus* *P. perfoliatus* *P. gramineus* *P.* x *nitens* Any other established hybrid of these *Potamogeton* species *Nitella* spp. *Sparganium natans* *Najas flexilis*
Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp.	*Chara* spp. (excluding *C. vulgaris*)	
Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation	*Potamogeton lucens* *P. perfoliatus* *P. coloratus* *P. praelongus* *P. x zizii* or any other hybrid with any of the above species as a parent *P. pusillus* *P. friesii* *P. obtusifolius* *P. berchtoldii* *P. trichoides* *P. filiformis* *P. crispus*	*Ranunculus circinatus* *Chara* spp. *Callitriche* spp. *Stratiores aloides* *Lemna* spp. *Hydrocharis morsus-ranae* *Riccia fluitans* *Utricularia australis/vulgaris* *Spirodela polyrhiza*
Natural dystrophic lakes and ponds	*Utricularia* spp. *Sphagnum* spp. *Juncus bulbosus*	*Nymphaea alba* *Menyanthes trifoliata* *Potamogeton polygonifolius*
Turloughs and Breckland Meres	Aquatic vegetation can include *Potamogeton* spp. and bryophytes.	

Common Standards Monitoring Guidance, using an approach similar to that for lakes, has also been drawn up for *Najas flexilis*, *Luronium natans*, canals and ditch systems.

6.2 Lake Habitat Survey (LHS)

Lake Habitat Survey (Rowan *et al.*, 2004, 2005, 2006) is a standard method for recording the physical features of lakes, determining their present condition, and monitoring change. This method is suitable for assessing aspects of

lakehydromorphology under the Water Framework Directive and the condition of lakes designated as SACs and SSSIs, with reference to the requirements of Common Standards Monitoring. The habitat structure provided by macrophyte vegetation is one aspect of lake morphology that is recorded in LHS, along with non-biotic features such as substrate and sedimentation. Macrophytes in the littoral zone are recorded under the following growth form categories (LHS recording form, 2008):

- Liverworts/mosses/lichens;
- Emergent broad-leaved herbs;
- Emergent reeds/sedges/rushes;
- Floating-leaved (rooted);
- Free-floating;
- Submerged broad-leaved;
- Submerged short, stiff-leaved;
- Submerged linear-leaved;
- Submerged fine- and dissected-leaved (including stoneworts);
- Filamentous algae;
- Phytobenthos;
- Seaweeds.

The arial cover of each vegetation type and the percent volume inhabited (PVI) are estimated in 15m wide plots, extending lakewards 10m from the waterline or to maximum wading depth. The following categories of vegetation cover and PVI are used:

- 0%
- > 0 – 1%
- > 1 - 10%
- > 10 - 40%
- > 40 - 75%
- > 75%.

Extension of vegetation lakewards beyond the recorded plot, and the presence of notable introduced plant species are also noted.

7 Plant Lake Ecotype Index (PLEX)

7.1 Trophic Ranking Score (TRS)

The first British lakes classification (Palmer, 1989; Palmer *et al.*, 1992) incorporated a Trophic Ranking Score (TRS) for individual plant species. These scores were derived by calculating the expected frequency of occurrence of each species across the nine freshwater site types, which were allocated to a series of four broad trophic classes: dystrophic, oligotrophic, mesotrophic and eutrophic. The brackish site type was not included in the analysis.

TRS ranged from 2.5 for *Sphagnum* spp., which are typical of highly acid, nutrient-poor waters, to 10 for species such as *Potamogeton pectinatus* that are typical of nutrient-rich waters (see Table 12). The TRS for a site is the mean of the scores for all the species present in the site. The TRS system was predicated on each site grouping being allocated a trophic status. There was very little information on nutrient levels to support this assumption. However, the scoring system was related to alkalinity, which was treated as a surrogate for nutrient status.

7.2 Pant Lake Ecotype Index (PLEX)

A similar system to TRS was developed as part of the revised lake classification scheme (Duigan *et al.*, 2006; Duigan *et al.*, 2007). It was named Plant Lake Ecotype Index, or PLEX (the term 'ecotype' referring to habitat, not plant taxonomy). PLEX values for the 62 submerged and floating taxa occurring in at least 25 sites in the dataset were calculated, using a modification of the method for calculating TRS. Instead of ascribing lake groups to trophic classes they were grouped into five ecological categories or 'ecotypes' (V to Z), as follows. Brackish water lakes (group J) were excluded, as before.

V	Dystrophic lakes	Lake group A
W	Heathland associated soft waters in lowlands and mountains	Lake groups B & C
X	Circum-neutral, mid to low altitude lakes	Lake groups D & E
Y	Hardwater lowland lakes	Lake groups F, G & H
Z	Hardwater lowland lakes, with *Chara*	Lake group I

A PLEX value for each species was calculated by examining its distribution across the lake groups and scoring its affinity to the five ecotypes. For details of the method used see Duigan *et al.* (2006) or Duigan *et al.* (2007). PLEX values ranged from 1.54 for *Sphagnum* spp., which are strongly associated with ecotypes V and W, to 9.23 for *Potamogeton freisii*, which is strongly associated with ecotype Z. Some species, for instance *Potamogeton gramineus*, occur predominantly in ecotype X, so have a 'middling' PLEX value (in this case 7.31). Other species, such as *Sparganium emersum* (PLEX value 7.5), are much more evenly spread across the ecotypes, and they also have a middling score, this time reflecting a lack of specialism. Table 12 shows PLEX values and the equivalent TRS scores. Figure 1 shows the close relationship between PLEX and TRS.

As with TRS, the average PLEX score for a site can be calculated from the PLEX values for the plants present. The average PLEX score at intervals over a 40 year period were calculated for Llangorse Lake, an impacted water body in Wales. The results show fluctuations that reflect changes in the composition of the macrophyte flora (Duigan *et al.*, 2006, 2007).

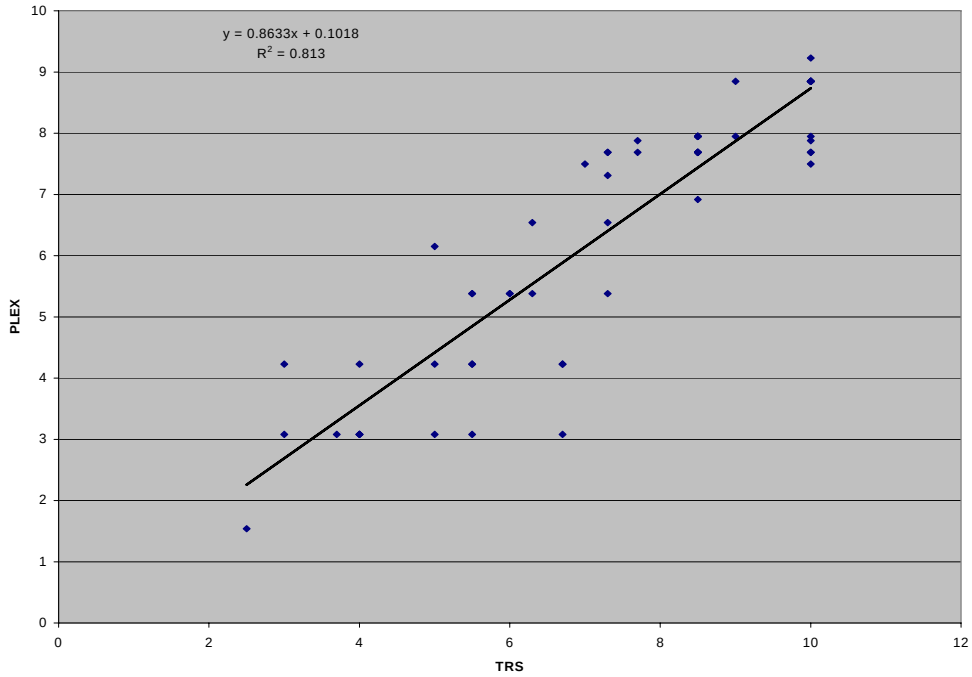

Figure 1. The relationship between PLEX and TRS

Table 12 PLEX, TRS and Ellenberg nitrogen scores

Taxa	PLEX	TRS	Ellenberg N
Sphagnum spp.	1.54	2.5	-
Eleogiton fluitans	3.08	4	2
Eriocaulon aquaticum	3.08	-	1
Juncus bulbosus	3.08	3.7	2
Lobelia dortmanna	3.08	5	1
Nymphaea alba	3.08	6.7	4
Pilularia globulifera	3.08	-	2
Potamogeton polygonifolius	3.08	3	2
Sparganium natans	3.08	5.5	3
Utricularia intermedia sens. lat.	3.08	4	2
Utricularia minor	3.08	4	2
Isoetes lacustris	4.23	5	1
Littorella uniflora	4.23	6.7	3
Myriophyllum alterniflorum	4.23	5.5	3
Potamogeton natans	4.23	6.7	3
Sparganium angustifolium	4.23	3	2
Subularia aquatica	4.23	4	2
Utricularia vulgaris sens. lat.	4.23	5.5	4
Elatine hexandra	5.38	6	4
Fontinalis antipyretica	5.38	6.3	-
Isoetes echinospora	5.38	-	2
Nitella spp.	5.38	5.5	-
Nuphar pumila	5.38	6	4
Potamogeton alpinus	5.38	5.5	5
Potamogeton praelongus	5.38	7.3	5
Callitriche hamulata	6.15	5	5
Glyceria fluitans	6.54	6.3	6
Potamogeton obtusifolius	6.54	7.3	5
Nuphar lutea	6.92	8.5	6
Potamogeton gramineus	7.31	7.3	3
Apium inundatum	7.50	7	4
Elodea canadensis	7.50	8.5	6
Sparganium emersum	7.50	10	6
Callitriche hermaphroditica	7.69	8.5	5
Callitriche stagnalis	7.69	7.7	6
Chara spp.	7.69	8.5	-
Potamogeton filiformis	7.69	10	5
Potamogeton berchtoldii	7.69	7.3	5
Potamogeton perfoliatus	7.69	7.3	5
Potamogeton gramineus x *lucens*	7.69	-	4
Potam. gramineus x *perfoliatus*	7.69	-	5
Ranunculus baudotii	7.69	10	6
Ranunculus hederaceus	7.69	8.5	5
Ranunculus trichophyllus	7.69	8.5	6
Ranunculus peltatus	7.69	8.5	6
Hippuris vulgaris	7.88	7.7	4
Potamogeton lucens	7.88	10	6

Taxa	PLEX	TRS	Ellenberg N
Eleocharis acicularis	7.95	8.5	5
Elodea nuttallii	7.95	10	7
Persicaria amphibia	7.95	9	6
Potamogeton crispus	7.95	8.5	6
Potamogeton pusillus	7.95	8.5	6
Ranunculus aquatilis	7.95	8.5	5
Ceratophyllum demersum	8.85	10	7
Enteromorpha spp.	8.85	-	-
Lemna minor	8.85	9	6
Lemna trisulca	8.85	10	5
Myriophyllum spicatum	8.85	10	7
Potamogeton pectinatus	8.85	10	7
Ranunculus circinatus	8.85	10	7
Zannichellia palustris	8.85	10	7
Potamogeton friesii	9.23	10	5

7.3 PLEX and fertility

Duigan *et al.* (2008) have demonstrated strong positive correlations between PLEX values and both pH and alkalinity. This is not surprising, given that PLEX values are derived from a site classification positively correlated with pH and alkalinity.

Hill *et al.* (2004) apply a scale indicating nitrogen preference to British vascular plant species. The scale is a modified version of the system first produced by Ellenberg *et al.*, 1991) for plants on mainland Europe. An Ellenberg nitrogen value of 1 indicates that the plant grows in very infertile situations; the maximum value of 8 indicates that the plant is found in extremely rich situations.

Table 12 shows the 'Ellenberg N' values given by Hill *et al.* to the aquatic vascular plants that also have PLEX values. Figure 2 shows the relationship between PLEX and Ellenberg N values. It is clear that low PLEX values are generally associated with plants of infertile waters and high PLEX values are associated with species found in much more fertile places.

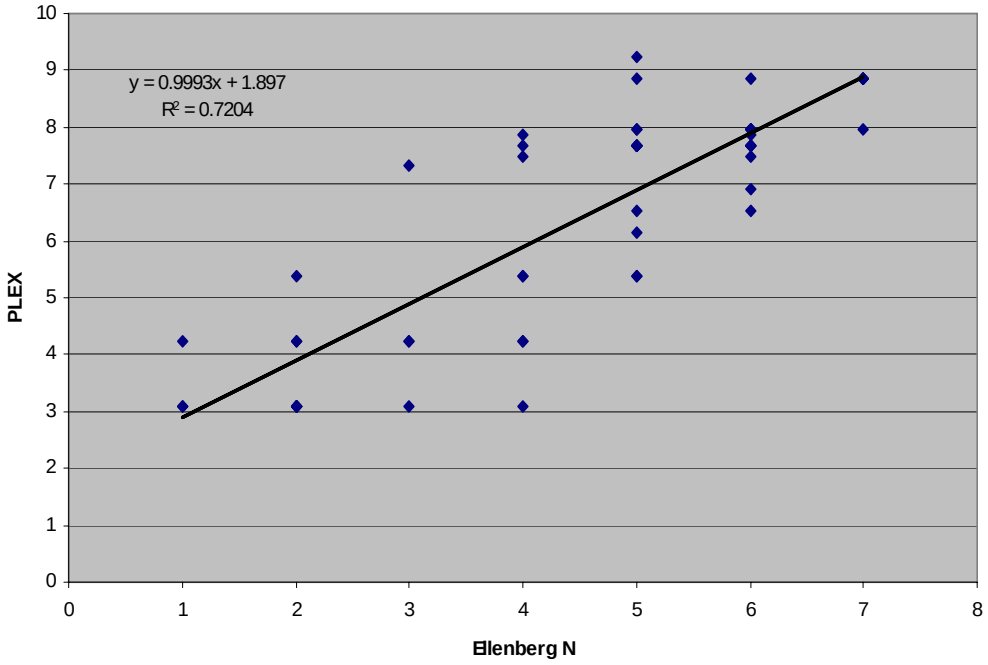

Figure 2. The relationship between PLEX and 'Ellenberg' nitrogen indicator values

7.4 PLEX, plant attributes, biogeography and decline

The attribute-based classification of aquatic macrophytes (Willby *et al.*, 2000) (see section 4.6) produced 20 groups of plants. The attribute group for each vascular plant given a PLEX value is shown in Table 13. Attribute group 12 comprises plants with soft, narrow, submerged leaves (amongst other characteristics) such as fine-leaved *Potamogetons* and some of the *Callitriche* species; Group 14 is made up exclusively of *Utricularia* species; group 20 comprises the isoetids, which have rigid, tubular, waxy leaves.

Duigan *et al.* (2008) show that plants in attribute group 20 are dominant in base-poor lake groups A to C, whereas plants in attribute group 20 are typical of base-rich lake groups G and I. Both attribute groups are well represented in lake groups D and E, which are the most species-rich of the lake groups.

According to Preston *et al.* (2002a), 23 of the 57 vascular plant taxa that were given PLEX values are less widespread now that they were before 1987. These declining species are indicated in Table 13. The attribute groups for which decline is most obvious are group 14, the utricularids, and group 20, the isoetids. Table 13 indicates that decline has been most marked in the lowlands of southern and eastern Britain, often as a result of eutrophication (Preston *et al.*, 2002a). Preston *et al.* (2002b) comment on the marked decline in the British Isles over the last half century of plant species associated with low nutrient habitats. Duigan *et al.* (2008) point out that 15 (60%) of the declining plants listed in Table 13 have low PLEX values (3.08 to 5.38), including all the isoetids and utricularids, whereas only 22 (39%) of the full suite of 57 plants have low values. Table 14 summarises this.

Hill *et al.* (2004) give information on the global distribution of native British vascular plants. Table 13 shows the biogeographical distribution of the species with PLEX values. Biogeographic elements and major biomes are defined as follows:

- Wide-boreal – from tundra to temperate zone
- Boreal-montane – main distribution in coniferous forest zone
- Boreo-temperate – in conifer and broadleaf zones
- Temperate – broadleaf forest zone
- Southern-temperate – Mediterranean region and broadleaf forest zone
- Wide-temperate – from Mediterranean region to coniferous forest zone

Eight boreal-montane species in Table 13, seven of which have low PLEX values, have declined. Boreal-montane species make up 35% of the declining species, but only 21% of the full suite of 57 vascular plant species with PLEX values (Duigan *et al.*, 2008). Preston *et al.* (2002b) note that species of more northern affinities have decreased, especially in southern Britain. In the face of climate change, altitude and climatic range are likely to become increasingly important factors influencing future species distribution.

These observations demonstrate how PLEX values can be interpreted as indicators of potential vulnerability to environmental pressures.

Table 13 PLEX, biogeographical biome, attribute group and indications of decline for aquatic vascular plants

Vascular plant species	PLEX	Biogeo. biome	Attribute group	Decline in Britain indicated in Preston *et al.* (2002a)
Utricularia intermedia sens. lat.	3.08	BM	14	South & East England
Lobelia dortmanna	3.08	BM	20	Eastern England & eastern Scotland
Sparganium angustifolium	4.23	BM	1	Eastern Scotland
Subularia aquatica	4.23	BM	20	Eastern & north west England
Isoetes lacustris	4.23	BM	20	Lowlands
Potamogeton alpinus	5.38	BM	4	England & eastern Scotland
Potamogeton praelongus	5.38	BM	15	England & Wales
Potamogeton filiformis	7.69	BM	17	Possibly eastern Scotland
Utricularia minor	3.08	BT	14	South & east England
Sparganium natans	3.08	BT	1	Lowlands
Utricularia vulgaris sens. lat.	4.23	BT	14	General decline
Myriophyllum alterniflorum	4.23	BT	16	Lowland England
Potamogeton obtusifolius	6.54	BT	12	General decline
Potamogeton gramineus	7.31	BT	4	England
Potamogeton friesii	9.23	BT	12	Lowlands
Pilularia globulifera	3.08	T	20	Eastern England
Potamogeton polygonifolius	3.08	T	4	South east England
Littorella uniflora	4.23	T	20	Lowlands
Apium inundatum	7.5	T	5	General, especially England
Potamogeton lucens	7.88	T	15	Northern England, eastern Scotland
Ranunculus circinatus	8.85	T	13	General decline
Eleogiton fluitans	3.08	ST	2	England
Ranunculus hederaceus	7.69	ST	10	Arable areas
Potam. gramineus x *perfoliatus*	7.69	-	-	South & east England
Potamogeton gramineus x *lucens*	7.69	-	-	Eastern Scotland, eastern England
Ranunculus trichophyllus	7.69	WB	5	-
Eriocaulon aquaticum	3.08	BM	20	-
Isoetes echinospora	5.38	BM	20	-
Nuphar pumila	5.38	BM	3	-
Callitriche hermaphroditica	7.69	BM	12	-
Juncus bulbosus	3.08	BT	20	-
Potamogeton natans	4.23	BT	4	-
Callitriche hamulata	6.15	BT	7	-
Nuphar lutea	6.92	BT	3	-
Sparganium emersum	7.5	BT	1	-
Potamogeton berchtoldii	7.69	BT	12	-
Potamogeton perfoliatus	7.69	BT	15	-
Hippuris vulgaris	7.88	BT	2	-
Eleocharis acicularis	7.95	BT	20	-
Persicaria amphibia	7.95	BT	6	-
Ranunculus peltatus	7.69	WT	5	-
Potamogeton pectinatus	8.85	WT	17	-
Nymphaea alba	3.08	T	3	-
Elatine hexandra	5.38	T	9	-
Glyceria fluitans	6.54	T	2	-
Callitriche stagnalis	7.69	T	7	-
Ranunculus aquatilis	7.95	T	8	-

Vascular plant species	PLEX	Biogeo. biome	Attribute group	Decline in Britain indicated in Preston *et al.* (2002a)
Lemna trisulca	8.85	T	18	-
Myriophyllum spicatum	8.85	T	16	-
Ranunculus baudotii	7.69	ST	8	-
Potamogeton crispus	7.95	ST	15	-
Potamogeton pusillus	7.95	ST	12	-
Lemna minor	8.85	ST	18	-
Ceratophyllum demersum	8.85	ST	13	-
Zannichellia palustris	8.85	ST	17	-
Elodea canadensis	7.5	(Am)	13	-
Elodea nuttallii	7.95	(Am)	13	-

Biogeographic biome (native species): WB = Wide-boreal; BM = Boreal-montane; BT = Boreo-temperate; WT = Wide-temperate; T = Temperate; ST = Southern-temperate; Am = N. America.

Table 14 PLEX values for declining and stable species

PLEX values	No. of declining species	No. of stable species
3.08	7	3
4.23	6	1
5.38	2	3
6.15 – 6.92	1	3
7.31 – 7.95	7	16
8.85 – 9.23	2	6

8 The Water Framework Directive

The EC Water Framework Directive aims to improve the ecological condition of surface waters (rivers and lakes) and groundwaters. Surface waters are classified according to the degree of departure from reference (pristine) condition, as defined by a number of physical and biological 'quality elements'. The five ecological classes are high, good, moderate, poor and bad. The aim is to achieve at least good quality for all waters.

In order to carry out fair comparisons between sites, British lakes are typed according to geology (using alkalinity as a surrogate), depth and, for some quality elements, altitude. For purposes of standardisation between member states, European lakes have been divided into Geographical Intercalibration Groups (GIGs), based on size, alkalinity, depth, altitude and humic content. In the UK, lakes in different parts of the country fall into three GIGs: Northern, Central and Atlantic types.

Aquatic macrophytes comprise one of the biological quality elements for which ecological status assessments of surface waters must be defined. In the UK, the LEAFPACS system has been designed to detect the impact on macrophytes of nutrient enrichment. LEAFPACS describes macrophyte species as responding negatively or positively to eutrophication pressure.

8.1 Indicators of eutrophication

Penning *et al.* (2008a and b) have classified aquatic macrophytes as indicators of eutrophication in European lakes, using LEAFPACS and other methods of assessing impact. Data on aquatic macrophytes and water quality (total phosphorus, chlorophyll a and Secchi depth) were gathered from 1,147 lakes in 12 European countries, 50 of them in the UK. Plant species were classified as sensitive, indifferent or tolerant to eutrophication. The investigation identified 23 vascular plant and four charophyte species that can be defined robustly as sensitive to eutrophication in Europe, and 20 vascular plant and one charophyte species that are tolerant of eutrophication. Tables 15 and 16 list the vascular plant species occurring in Britain that are regarded by Penning *et al.* (2008a) as sensitive and tolerant, together with their TRS values (Palmer *et al.*, 1992) and PLEX values (Duigan *et al.*, 2007). Alkalinities of <1 meq l^{-1} are defined as low and alkalinities of >1 meq l^{-1} as high.

As might be expected, most of the species regarded by Penning *et al.* (2008a) as sensitive to eutrophication have low TRS values (3.0 – 5.0) and low PLEX scores (3.08 – 5.38) (see Table 15). However, *Callitriche hamulata* has a moderately high PLEX value (6.13), although its TRS value is low (5.0), and *Ranunculus peltatus* has a high TRS value (8.5) and a fairly high PLEX value (7.69). The most glaring difference is shown by *Potamogeton filiformis*, which has a very high TRS value (10.0) and a fairly high PLEX value (7.69). This species is generally regarded as characteristic of base-rich, eutrophic or brackish sites in Britain (Preston, 1995; Preston *et al.*, 1992). Its Ellenberg nitrogen value (5) is moderate.

Almost all the species regarded as tolerant of eutrophication at the European scale have high TRS values (8.5 – 10.0) and high PLEX values (7.95 - 8.85). However, *Potamogeton obtusifolius* has moderate TRS (7.4) and PLEX (6.54) values and is

generally regarded in Britain as a plant of mesotrophic to meso-eutrophic conditions (Preston & Croft, 1997; Preston *et al.*, 1992). Its Ellenberg nitrogen value (5) is the same as for *Potamogeton filiformis*.

Table 15 European vascular plant species regarded as sensitive to eutrophication

Sensitive plant species	TRS	PLEX	Further information using LEAFPACS
Callitriche hamulata	5.0	6.13	
Eleocharis acicularis	8.5	7.95	Tolerant in high alkalinity Northern GIG lakes
Isoetes echinospora	-	5.38	
Isoetes lacustris	5.0	4.23	
Littorella uniflora	6.7	4.23	Very sensitive in high alkalinity Central GIG but tolerant in high alkalinity Northern GIG lakes
Lobelia dortmanna	5.0	3.08	
Myriophyllum alterniflorum	5.5	4.23	Very sensitive in high alkalinity Central and Northern GIG lakes
Nuphar lutea x *pumila*	-	-	
Potamogeton filiformis	10.0	7.69	Very sensitive in high alkalinity Central GIG lakes
Potamogeton polygonifolius	3.0	3.08	Very sensitive in low alkalinity Northern GIG lakes
Potamogeton x *nitens*	-	7.69	Tolerant in low alkalinity Northern GIG lakes
Potamogeton x *zizii*	-	7.69	Tolerant in low alkalinity Northern GIG lakes
Ranunculus peltatus	8.5	7.69	
Ranunculus reptans	-	-	
Sparganium angustifolium	3.0	4,23	Very sensitive in high alkalinity Northern GIG lakes
Subularia aquatica	4.0	4.23	
Utricularia australis	-	-	Tolerant in low alkalinity Northern GIG lakes
Utricularia intermedia	4.0	3.08	
Utricularia minor	4.0	3.08	
Utricularia ochroleuca	-	-	Very sensitive in low alkalinity Northern GIG lakes

Table 16 European vascular plant species regarded as tolerant of eutrophication

Tolerant plant species	TRS	PLEX
Ceratophyllum demersum	10.0	8.85
Elodea nuttallii	10.0	7.95
Hydrocharis morsus-ranae	-	-
Lemna minor	9.0	8.85
Lemna trisulca	10.0	8.85
Myriophyllum verticillatum	-	-
Nymphoides peltata	-	-
Potamogeton crispus	8.5	7.95
Potamogeton obtusifolius	7.4	6.54
Potamogeton pectinatus	10.0	8.85
Potamogeton pusillus	8.5	7.95
Potamogeton trichoides	-	-
Ranunculus circinatus	10.0	8.85
Spirodela polyrrhiza	-	-
Stratiotes aloides	-	-
Zannichellia palustris	10.0	8.85

8.2 Lake Macrophyte Nutrient Index (LMNI)

A draft report on lake assessment methods, produced by the UK Water Framework Directive Technical Advisory Group (WFD-UKTAG, October 2008), lists Lake Macrophyte Nutrient Index (LMNI) scores for a large number of macrophyte species (including charophytes), as part of the LEAFPACS system. LMNI scores range from 1 for *Uricularia ochroleuca*, indicating extreme sensitivity to nutrient enrichment, to 10 for *Ruppia maritima*, indicating extreme tolerance to eutrophication.

Table 17 lists the LMNI scores for all the taxa for which there are TRS and/or PLEX values.

Table 17 TRS, PLEX and LMNI values

Species	TRS	PLEX	LMNI (LEAFPACS)
Sphagnum spp.	2.5	1.54	3.37
Potamogeton polygonifolius	3	3.08	3.50
Sparganium angustifolium	3	4.23	3.65
Juncus bulbosus	3.7	3.08	3.72
Eleogiton fluitans	4	3.08	3.45
Eriocaulon aquaticum	-	3.08	1.67
Subularia aquatica	4	4.23	2.93
Utricularia intermedia	4	3.08	2.19
Utricularia minor	4	3.08	2.97
Callitriche hamulata	5	6.15	5.47
Isoetes lacustris	5	4.23	3.09
Isoetes echinospora	-	5.38	4.06
Lobelia dortmanna	5	3.08	2.46
Myriophyllum alterniflorum	5.5	4.23	4.54
Nitella spp.	5.5	5.38	5.47
Potamogeton alpinus	5.5	5.38	5.79
Sparganium natans	5.5	3.08	4.84
Utricularia vulgaris agg.	5.5	4.23	5.28
Elatine hexandra	6	5.38	5.41
Nuphar pumila	6	5.38	5.33
Fontinalis antipyretica	6.3	5.38	5.42
Glyceria fluitans	6.3	6.54	-
Littorella uniflora	6.7	4.23	4.70
Nymphaea alba	6.7	3.08	5.54
Potamogeton natans	6.7	4.23	5.16
Apium inundatum	7	7.50	5.69
Potamogeton berchtoldii	7.3	7.69	6.07
Potamogeton gramineus	7.3	7.31	5.51
Potamogeton obtusifolius	7.3	6.54	6.72
Potamogeton perfoliatus	7.3	7.69	5.83
Potmogeton praelongus	7.3	5.38	5.77
P. gramineus x *perfoliatus*	-	7.69	5.60
P. gramineus x *lucens*	-	7.69	5.69
Callitriche stagnalis	7.7	7.69	5.98
Hippuris vulgaris	7.7	7.88	6.40
Callitriche hermaphroditica	8.5	7.69	6.71
Chara spp.	8.5	7.69	6.31
Eleocharis acicularis	8.5	7.95	6.75
Elodea canadensis	8.5	7.95	7.14
Nuphar lutea	8.5	6.92	6.92
Potamogeton crispus	8.5	7.95	7.64
Potamogeton pusillus	8.5	7.95	7.61
Ranunculus aquatilis	8.5	7.95	6.61
Ranunculus hederaceus	8.5	7.69	6.60
Ranunculus peltatus	8.5	7.69	6.48
Ranunculus trichophyllus	8.5	7.69	-

Species	TRS	PLEX	LMNI (LEAFPACS)
Lemna minor	9	8.85	7.58
Persicaria amphibia	9	7.95	7.25
Ceratophyllum demersum	10	8.85	8.67
Elodea nuttallii	10	7.95	6.92
Lemna trisulca	10	8.85	7.82
Myriophyllum spicatum	10	8.85	7.84
Potamogeton filiformis	10	7.69	6.16
Potamogeton friesii	10	9.23	7.64
Potamogeton lucens	10	7.88	7.02
Potamogeton pectinatus	10	8.85	8.25
Ranunculus baudotii	10	7.69	6.82
Ranunculus circinatus	10	8.85	8.64
Sparganium emersum	10	7.50	6.59
Zannichellia palustris	10	8.85	8.49
Pilularia globulifera	-	3.08	5.18
Enteromorpha	-	8.85	8.42

Figures 3 and 4 show the relationship between LMNI scores for macrophytes and TRS and PLEX values. The overall correspondence between LMNI scores and both TRS and PLEX values is close, even though TRS and PLEX are indicators of alkalinity, rather than nutrient status. This reflects the fact that alkalinity and nutrient status are closely related, particularly in non-impacted waters. Outliers are *Lobelia dortmanna* and *Potamogeton filiformis* for TRS, *Eriocaulon septangulare* and *Nymphaea alba* for PLEX, and *Utricularia intermedia* for both TRS and PLEX.

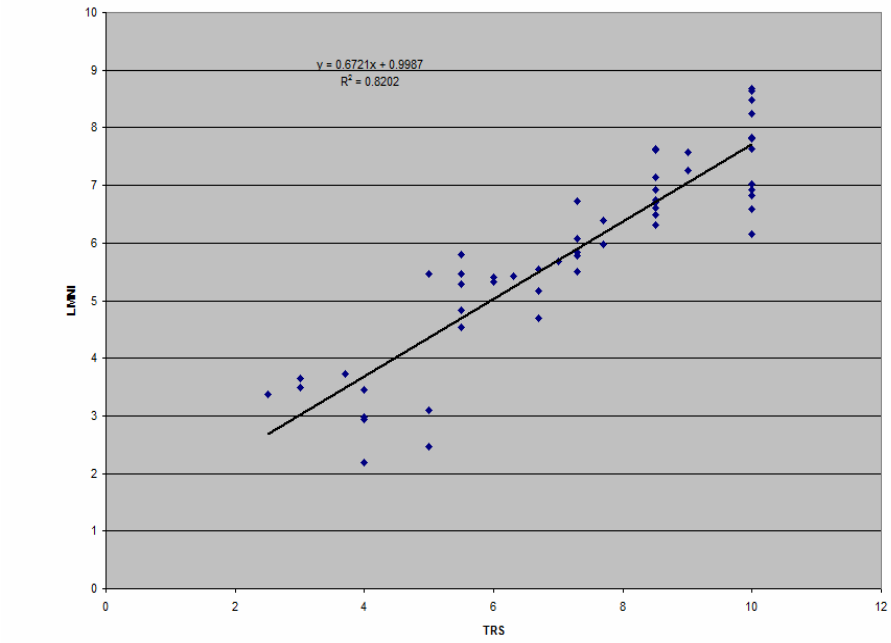

Figure 3. The relationship between TRS values and LMNI scores

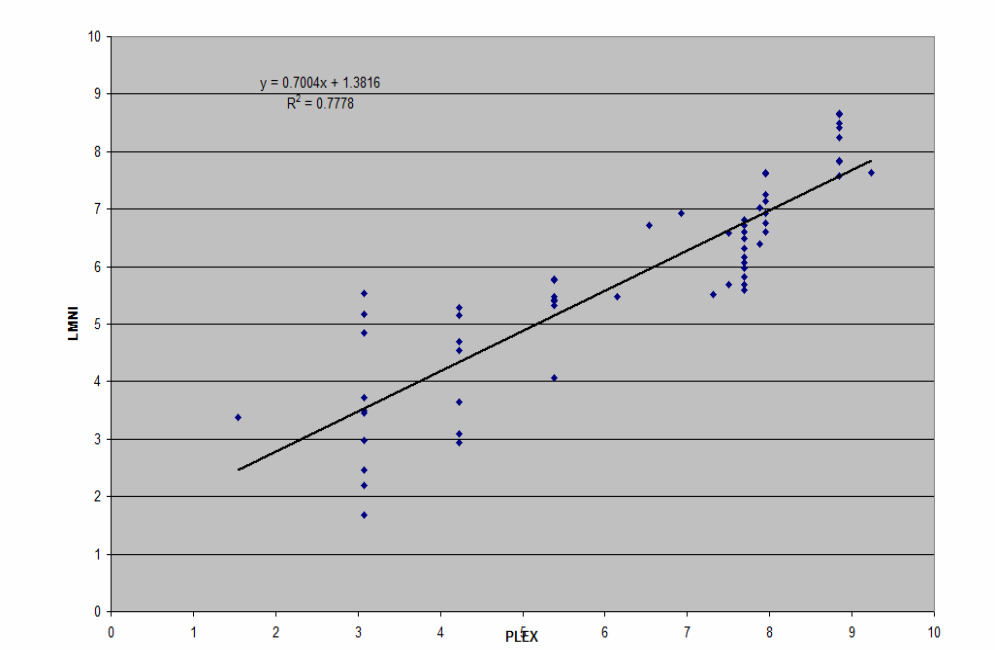

Figure 4. The relationship between PLEX values and LMNI scores

In the LEAFPACS system, the Lake Macrophyte Nutrient Index for a site is the mean of the scores for all the species present in the sampled area (*cf.* TRS and PLEX systems).

LEAFPACS produces an Ecological Quality Ratio (EQR) for the macrophyte assemblage of a lake. This is a combined ratio of observed values to reference values, for five different parameters:

- Lake Macrophyte Nutrient Index (LMNI)
- number of functional groups of macrophyte taxa (see Willby *et al.*, 2000)
- number of macrophyte taxa
- mean percent cover of hydrophytes
- relative percent cover of filametous algae

The complex calculations used to produce reference values take account of the alkalinity, depth, altitude, surface area, conductivity, geology, distance from the coast and acid neutralising capacity of the lake.

The proposed aquatic macrophyte standards for lakes, for application with the lake LEAFPAS method (WFD-UKTAG, October 2008) are as follows:

Condition of quality element	**Adjusted LEAFPACS EQR (mean July – mid Sept)**
High	0.8
Good	0.6
Moderate	0.4
Poor	0.2

8.3 Alien species

Under the Water Framework Directive, a water body is classed as worse than good status if there is evidence that an alien species on the high impact list is causing biological quality elements to deviate more than slightly from their reference condition (WFD-UKTAG, December 2007). The aquatic macrophytes provisionally included on the high impact list for Britain are indicated in Table 3 (*Lemna minuta* and *Nymphoides peltata* are also regarded as high impact species in Northern Ireland). In addition, four terrestrial plant species – Japanese knotweed *Fallopia japonica*, giant hogweed *Heracleum mantegazzianum*, Himalayan balsam *Impatiens glandulifera* and Rhododendron *Rhododendron ponticum* – are included on the list because of their adverse impacts on the condition of riparian and shore zones.

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