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Update to quick reference to fens

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W J Fojt

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Background to this report

This report is intended to update 'Quick Reference to Fens' CSD note No. 45 which was produced in 1989. The 1989 version was an attempt to summarise in tabular form the habitat conditions, stand size and distributional characteristics, management and threats of British fen communities using information from the NVC and research results from Wheeler and Shaw (1987) from Sheffield University.

Since 1989 further information on habitat conditions and environmental characteristics of poor fen communities (Shaw and Wheeler 1990) has become available thus completing a study of the suite of lowland rich and poor fen vegetation types. Furthermore, the data from both the rich and poor fen surveys has been analysed together in order to establish the nature of environmental and management differences between the full range of communities and to identify the scientific differences between rich and poor fens. This analysis involving the use of DCA (detrended correspondence analysis) and CCA (canonical correspondence analysis) gives a new perspective on the data presented in the rich and poor fen reports.

The research of Sheffield University

Prior to considering in greater detail the nature of the report, the context of the information needs to be summarised by referring to the research of Sheffield University.

The environmental, management and floristic data was gathered from 368 fens throughout Great Britain using 995 quadrats. Fens featuring examples of specific communities were visited from a wide geographical spread and as wide a range of hydrotopographic (valley, flood plain etc.) types as possible. Inevitably, it was not possible to sample fens in all areas and therefore areas which were known to have fens were purposefully targeted. This clearly has implications for Scotland where the fen resource was not comprehensively known. In addition, sites sampled in Scotland tended to have high conservation importance i.e. most are SSSI, and lower quality sites were undersampled.

The rich fen survey was undertaken prior to the publication of the draft and published NVC Mire and Swamp and Tall herb fen chapters, and communities were sampled according to types described by Wheeler (1980 a,b,c). The analysis of the all the rich and poor fen data allowed these community types to be translated into NVC types and in most cases this was straightforward. But there are two exceptions, *Peucedano-Phragmitetum caricetosum* and *Cladio-Molinietum* for which there are no exact NVC equivalents. Therefore, these have been retained. Furthermore, analysis of quadrat data also identified a number of variants which have not been described by the NVC, these have also been retained.

The analysis of the rich and poor fen data together has been very important in defining the differences between communities in

terms of environmental variables and to clarify, especially, the relationship between those communities which appeared from earlier work to straddle the rich-fen - poor-fen boundary, S27 *Carex rostrata-Potentilla palustris* fen and M9 *Carex rostrata-Calliergon cuspidatum* mire. Analysis of the vegetation data and environmental variables used multivariate statistics to highlight inter-relationships and their strengths. In addition, a full range of principle fen species (PFS) and rare fen species (RFS) has been identified (Table 1). The value for conservation of categorising species in this way these species can be gained from Wheeler (1988). The work also identified ranges in environmental variables, so that terms used within this report such as low or very high refer specifically to a given range in values of a variable. These ranges are given in Table 2.

The organisation of the report

The organisation of this report follows that of 1989 i.e. communities are grouped into three categories; those largely associated with topogenous fens, communities largely associated with soligenous fens and fen meadow communities (Table 3). This does not mean that these communities are confined to these broad fen types, but they have a tendency to occur in these types. Fen meadow communities and M27 *Filipendula ulmaria-Angelica sylvestris* mire can occur in topogenous as well as soligenous fen and are therefore treated separately. Certain communities have not been included, these are largely the communities of upland areas which were not sampled.

Table 4 summarises information in relation to habitat conditions and Table 5 summarises the management and environmental influences together with threats and impacts.

Terminology

There is a wealth of confusing terminology which should be defined.

Mire: The NVC clearly differentiates mires from swamp and tall herb fens. It includes within mires ombrotrophic (bog) vegetation as well as minerotrophic vegetation (fen). However, it is accepted by most bog and fen ecologists that mires may or may not be peat accumulating and they include both bogs and fens.

Swamp: This term was defined by Tansley (1939) as wetland sites with standing water supporting various (usually graminoid) immersive herbaceous perennials. However, they do not need to occupy flooded sites, for example reed beds may occupy very dry sites.

Tall herb fen: This describes the structure of the vegetation.

Topogenous: Relates to fens where vertical water table movements are more important than lateral water table movement. The fens include the following types: flood plain, basin, open water transition.

Soligenous: Relates to fens where horizontal water movement is more important than vertical water movement. Soligenous fen types include spring-fed systems which may occur as a discrete unit or along a valley, valley fen.

The identification of the fen hydromorphological or hyrotopographic type is not always easy and there may be elements of each type within any one site, for example flood plain fens may have spring inputs and valley fens may contain old peat cuttings which are topogenous in character.

Rich and Poor fen: On the continent rich and poor fens are recognised as a continuum which can be defined in terms of environmental variables. However, this definition does not strictly apply to British fens. The working definition of rich fens (with a pH >5.5) and poor fens (with a pH <6.0) was confirmed by Sheffield's studies, and further definition in terms of other environmental variables was possible. These are summarised in Table 6.

Species richness: Species richness was measured in three ways:

Species density: the number of species within a 2 x 2m quadrat.

Principle fen species (score) PFS(S): the number of principle fen species recorded in the same quadrat.

Rare fen species (score) RFS(S): the number of rare principle fen species recorded in the same quadrat.

Base richness: This term encompasses water and substratum pH, calcium and bicarbonate concentrations.

Ionic strength: This term encompasses conductivity values, sodium and magnesium concentrations.

Fertility and fertile: This refers to the ability of the substrate to support plant growth as estimated phytometrically. (Phytometry is the measure of growth made by a species in a given time period under standard conditions. In the case of rich fens *Epilobium hirsutum* was used and in the case of poor fens *Phalaris arundinacea* was used).

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TABLE 1 LIST OF SPECIES REGARDED AS PRINCIPAL FEN SPECIES AND RARE FEN SPECIES

Principal fen species:

Alnus glutinosa
Anagallis tenella
Angelica sylvestris
Aquilegia vulgaris
Calamagrostis canescens
Caltha palustris
Carex acutiformis
Carex curta
Carex demissa
Carex disticha
Carex echinata
Carex lepidocarpa
Carex nigra
Carex otrubae
Carex panicea
Carex paniculata
Carex pseudocyperus
Carex riparia
Carex rostrata
Carex vesicaria
Chrysosplenium oppositifolium
Cirsium palustre
Dactylorhiza incarnata
Dactylorhiza maculata
Dactylorhiza fuchsii
Dactylorhiza majalis praetermissa
Drosera rotundifolia
Eleocharis multicaulis
Eleocharis palustris
Eleocharis uniglumis
Epilobium parviflorum
Epilobium hirsutum
Epilobium obscurum
Epilobium palustre
Equisetum fluviatile
Equisetum palustre
Equisetum telmateia
Equisetum variegatum
Eriophorum angustifolium
Eupatorium cannabinum
Filipendula ulmaria
Frangula alnus
Galium palustre
Galium uliginosum
Glyceria maxima
Glyceria plicata
Hydrocotyle vulgaris
Hypericum tetrapterum
Hypericum elodes
Iris pseudacorus
Juncus acutiflorus
Juncus articulatus
Juncus bulbosus
Juncus effusus
Listera ovata
Lotus uliginosus
Lychnis flos-cuculi
Lycopus europaeus
Lysimachia vulgaris
Lythrum salicaria
Mentha aquatica
Menyanthes trifoliata
Molinia caerulea
Myosotis laxa
Myosotis scorpioides
Myrica gale
Narthecium ossifragum
Oenanthe crocata
Oenanthe fistulosa
Pedicularis palustris
Pedicularis sylvatica
Phalaris arundinacea
Phragmites australis
Potamogeton polygonifolius
Potentilla palustris
Pulicaria dysenterica
Ranunculus flammula
Rhyncospora alba
Rumex hydrolapathum
Salix aurita
Salix cinerea
Salix pentandra
Salix phylicifolia
Salix repens
Salix triandra
Salix viminalis
Scrophularia auriculata
Scutellaria galericulata
Sparganium erectum
Stellaria alsine
Symphytum officinale
Triglochin palustris
Typha angustifolia
Typha latifolia
Vaccinium oxycoccus
Valeriana dioica
Viola palustris

Aneura pinguis
Aulacomnium palustris
Bryum pseudotriquetrum
Calliergon cordifolium
Calliergon cuspidatum
Campylium stellatum
Chara vulgaris
Chiloscyphus pallescens
Chiloscyphus polyanthos
Cladiopodiella fluitans
Drepanocladus exannulatus
Drepanocladus fluitans
Drepanocladus revolvens
Dryopteris carthusiana
Fissidens adianthoides
Kurzia pauciflora
Mylia anomala
Mylia taylori
Odontoschisma sphagni
Philonotis fontanum
Plagiomnium rostrata
Polytrichum alpestre
Sphagnum auriculatum
Sphagnum capillifolium
Sphagnum fimbriatum
Sphagnum palustris
Sphagnum papillosum
Sphagnum recurvum
Sphagnum squarrosum
Sphagnum subnitens
Sphagnum subsecundum

Rare fen species:

Bartsia alpina
Blysmus compressus
Calamagrostis scottica
Calamagrostis stricta
Carex acuta
Carex appropinquata
Carex aquatilis
Carex chordorhiza
Carex diandra
Carex dioica
Carex distans
Carex elata
Carex elongata
Carex hostiana
Carex lasiocarpa
Carex limosa
Carex magellanica
Carex pauciflora
Carex pulicaris
Carex serotina
Cicuta virosa
Cirsium dissectum
Cladium mariscus
Cyperus longus
Dactylorhiza traunsteineri
Dactylorhiza majalis purpurella
Drosera anglica
Drosera intermedia
Dryopteris cristata
Eleocharis quinqueflora
Epipactis palustris
Erica ciliaris
Eriophorum latifolium
Eriophorum gracile
Euphrasia pseudokerneri
Gymnadenia borealis
Gymnadenia conopsea
Hammarbya palustris
Hierochloe odorata
Hypericum undulatum
Juncus alpino-articulatus
Juncus subnodulosus
Kobresia simpliciuscula
Lathyrus palustris
Liparis loeselii
Lysimachia thyrsiflora
Myosotis secunda
Oenanthe lachenalii
Osmunda regalis
Parentucellia viscosa
Parnassia palustris
Peucedanum palustre
Pinguicula lusitanica
Pinguicula vulgaris
Potamogeton coloratus
Primula farinosa
Pyrola rotundifolia
Ranunculus lingua
Sagina nodosa
Salix pentandra
Samolus valerandi
Saxifraga aizodes
Scheuzeria palustris
Schoenus ferrugineus
Schoenus nigricans
Scirpus fluitans
Scirpus setaceus (Isolepis)
Scutellaria minor
Selaginella selaginoides
Selinum carvifolia
Sium latifolium
Sonchus palustris
Sparganium minimum
Spiranthes romanzoffiana
Stellaria palustris
Thalictrum flavum
Thelypteris palustris
Tofieldia pusilla
Utricularia intermedia
Utricularia minor
Veronica scutellata
Viola persicifolia

Calliergon sarmentosum
Calliergon stramineum
Calliergon giganteum
Campylium elodes
Campylium polygamum
Cinclidium stygium
Cratoneuron commutatum
Drepanocladus lycopodioides
Drepanocladus sendtneri
Drepanocladus vernicosus
Homalothecium nitens
Moerkia flotoviana
Pellia endiviifolia
Philonotis caespitosa
Philonotis calcarea
Philonotis fontanum
Plagiomnium elipticum
Plagiomnium elatum
Pleurozia purpurea rare
Preissia quadrata
Pseudobryum cinclidioides
Rhizomnium pseudopunctatum
Riccardia chamedryfolia
Riccardia multifida
Scorpidium scorpioides
Sphagnum contortum
Sphagnum pulchrum
Sphagnum teres
Sphagnum warnstorfii

TABLE 2 APPROXIMATE VALUES FOR EACH VARIABLE USED TO EVALUATE THE TERMS 'VERY LOW', 'LOW', 'MODERATE', 'HIGH', AND 'VERY HIGH'

	v. low	low	moderate	high	v. high
Species density (4 m^{-2})	5-10	10-15	15-25	25-30	30-35
PFS score (4 m^{-2})	<9	9-13	14-19	20-27	>27
RFS score (4 m^{-2})	<1.0	1.1-2.5	2.6-5.0	5.1-8.0	>8.0
Water pH	<4.0	4.0-5.0	5.0-6.0	6.0-7.0	>7.0
Substratum pH	<4.0	4.0-5.0	5.0-6.0	6.0-7.0	>7.0
Conductivity (uS cm^{-1})	50-100	100-200	200-400	400-600	600-1000
Bicarbonate (mg l^{-1})	10-20	20-50	50-150	150-250	250-400
Water depth (cm)	< -25	-25 - -10	-9 - +1	+1 - +9	>+10
Redox potential (E7, mV)	<240	240-260	261-300	301-360	>360
Ca (mg 1 $peat^{-1}$)	200-400	400-600	600-1000	1000-1500	1500-2000
Mg (mg 1 $peat^{-1}$)	<20	21-50	51-100	101-140	>140
Na (mg 1 $peat^{-1}$)	<15	16-35	36-70	71-120	>120
Fe (rich fens) (mg 1 peat-1)	<0.1	0.1-0.5	0.5-2.0	2.0-10.0	>10.0
Fe (poor fens) (mg 1 $peat^{-1}$)	<40	41-80	81-120	121-160	>160
Mn (mg 1 $peat^{-1}$)	<1	1-6	7-20	21-60	>60
A1 (mg 1 $peat^{-1}$)	<15	16-25	26-40	41-80	>80
N (mg 1 $peat^{-1}$)	<1.0	1.1-3.0	3.1-6.0	6.1-10.0	>10.0
P (mg 1 $peat^{-1}$)	<0.1	0.1-0.3	0.3-0.5	0.5-1.1	>1.1
K (mg 1 $peat^{-1}$)	<9	9-19	19-29	29-43	>43
Phytometer biomass (mg $plant^{-1}$)	<3	3-9	10-20	21-35	>35

Table 3

Fen vegetation types fen featured in this report.

Topogenous fen communities

M1 *Sphagnum auriculatum* bog pool
M2 *Sphagnum cuspidatum / recurvum* bog pool
M4 *Carex rostrata-Sphagnum recurvum* mire
M5 *Carex rostrata-Sphagnum squarrosum* mire
M9 *Carex rostrata-Calliergon cuspidatum* mire
S4 *Phragmites australis* swamp and reed beds
S5 *Glyceria maxima* swamp
S2 *Phragmites australis-Peucedanum palustre* fen Peucedano-Phragmitetum caricetosum*
S25 Phragmites australis-Eupatorium cannabinum fen
S26 Phragmites australis-Urtica dioica fen
S27 *Carex rostrata-Potentilla palustris fen*
W2 *Salix cinerea-Betula pubescens-Phragmites australis* woodland, *Betulo-Dryopteridetum cristatae**

Soligenous fen communities

M6 *Carex echinata-Sphagnum recurvum / auriculatum* mire
M10 *Carex dioica-Pinguicula vulgaris* mire
M13 *Schoenus nigricans-Juncus subnodulosus* mire
M14 *Schoenus nigricans-Narthecium ossifragum* mire
M15 *Scirpus cespitosus-Erica tetralix* wet heath, M15a *Carex panicea* sub-community
M21 *Narthecium ossifragum-Sphagnum papillosum* mire
M29 *Hypericum elodes-Potamogeton polygonifolius* soakway
M30 Related vegetation of seasonally-inundated habitats (*Eleocharis multicaulis* water tracks)

Fen Meadows

M22 *Juncus subnodulosus-Cirsium palustre* fen meadow
M23 *Juncus effusus / acutiflorus-Galium palustre* rush pasture (*J. acutiflorus* sub-community)
M24 *Molinia caerulea-Cirsium dissectum* fen meadow *Cladio-Molinietum**
M25 *Molinia caerulea-Potentilla erecta* mire
M27 *Filipendula ulmaria-Angelica sylvestris* mire

* Wheeler communites

Topogenous fens

Community	Description	Habitat Conditions
M1 *Sphagnum auriculatum* bog pool	A very species-poor community (mean species density: 10.3 spp.4m^{-2}) stands include *Scheuzeria palustris* sampled on Rannoch Moor (Perth.). Often occurs as a raft or masses of submerged *S. auriculatum*. Floristic and environmental analysis has identified 2 sub-communities (provisional).	Principally a community of ombrotrophic bogs, especially with surface patterning, but can be found in poor fens of basin mires or in pools and water-tracks of valley mires. The conditions noted here relate to poor fens and are not representative of the community as a whole. Generally typical of permanently waterlogged conditions, often forming a soft raft of *Sphagnum*.
M1a Typical sub-community	This sub-community mainly comprising wet lawns (or submerged) *S. auriculatum* with a sparse assemblage of vascular associates. Low species density, range 6-16 spp. 4m^{-2}.	Water levels ≥ surface, redox levels low indicating generally stagnant conditions. Water is base poor and significantly lower in pH and bicarbonate than M1b. Conductivities were very low, significantly lower than for M1b. Na and Mg values were respectively low and moderate. Mn and Al values were very low. Only recorded from substrata of low fertility with moderate P and K levels. Mean N concentration was high, significantly higher than M1b.
M1b Provisional sub-community	This provisional sub-community contains in addition to *S. auriculatum*, *C. limosa*, also often *C. rostrata*, *E. multicaulis* and *P. polygonifolius*. May also contain other bryophytes eg *C. stellatum*, *S. scorpiodes*, *D. revolvens*, *S. contortum*. But still very low species density, range 7-13 spp. 4m^{-2}. Has floristic affinities with M29 and M30.	Mainly found in water-tracks or pools in valley and basin mires, but also in blanket mire. Water levels ≥ surface, redox levels low. Mean values of pH, bicarbonate and Ca generally low - moderate but significantly greater than M1. Conductivity low to moderate. Al values generally low. Low P and K. Concentrations of N moderate-high, but significantly lower than M1a. Fertility of substrate low.
M2 *Sphagnum cuspidatum/ recurvum* bog pool	*Sphagnum cuspidatum* and *S. recurvum* often form a wet raft with a scattering of vascular plants eg *E. angustifolium*, *D. rotundifolia*, *E. tetralix*. A separate sub-community characterised by *R. alba* is recognised (NVC). In general, species density is low (11.3 spp. 4m^{-2}). Very few rare species recorded.	Often associated with ombrotrophic mires, but can be found in poor fens of basin mires or forming the pools, re-colonised peat cuttings, and water tracks within valley mires. The conditions noted here relate to the poor-fen end of the spectrum and are not representative of the community as a whole.
M2a *R. alba* sub-community	This sub-community has a low mean species density.	This type is generally more common on active raised bogs which have not been surveyed and only 3 records made (Cornwall, Hants and Cumbria) from valley mires. Most of the environmental conditions were typical of the community and mainly not significantly different from M2b, indicating a trend towards the more ombrotrophic environments.
M2b *S. recurvum* sub-community		Water levels generally ≥ surface and redox levels correspondingly generally low. Mean Na concentrations were moderate. There was an interesting +ve relationship between Na concentration and species richness (species density, PFS and RFS scores). Mean conductivity levels are low. Mean concentrations of Mn and Al were respectively low and moderate. Fe levels were generally low and there was a -ve relationship between Fe concentration and PFS and RFS scores. Substratum fertility was typically low. The mean N concentration was high, but low mean P and K presumably acting as limiting factors to the plant response.
M4 *Carex rostrata-Sphagnum recurvum* mire	Characterised by a cover of sedges (commonly *C. rostrata*) over a carpet of semi-aquatic *Sphagna*, with generally few vascular plants. Mean species density was low (14.5 spp. 4m^{-2}), ranking the lowest of the main poor fen communities examined (excluding M1, M2 and M30) and significantly lower than M6 with which it is often associated.	Characteristic of topogenous situations; mire type and also pools and former peat cuttings in soligenous mires. Water levels were typically close to the surface and found within a narrow range of -10 to +10 cm. Redox potentials were generally low, but with a wide range reflecting the presence of the community in both soligenous and topogenous mires. Moderate to low conductivity, Na and Mg concentrations. Mn concentrations were low and those of Al and Fe were very low. N, P and K concentrations were generally moderate or high, but mean fertility was moderate to low, possibly indicating that base poverty was more limiting to plant growth than the availability of plant nutrients. But there was significant, +ve relationship between fertility and N concentration.

		In respect to the measured environmental variables this community is intermediate between M2 and M5, and is found in slightly more base poor, but more fertile situations than M6, particularly regarding K concentrations.
M5 *Carex rostrata-Sphagnum squarrosum* mire	A fairly heterogenous community characterised by the dominance of sedges with scattered poor-fen herbs over a patchy carpet of moderately base-tolerant *Sphagna*. Typically of moderate species richness (mean species density 20.8 spp. $4m^{-2}$). May often be found in association with S27 occupying situations of similar fertility, but of generally lower base status and water levels.	Typically found in topogenous mires, but can be found in soligenous mires. Often forms a flating raft with mean water level at the surface, though examples were recorded from -45–+11 cm. Redox values had a high range. Mainly found in conditions of low base status. Mean conductivity values and Na concentration were low, but mean Mg values were moderate. Concentration of Mn, Fe, Al were low. The community was found over a wide range of substratum fertilities, but the mean value was moderate, ranking second highest of poor fen communities. Concentrations of N, P and K were typically high, with highest mean P concentration of the poor-open fen communities. The substratum fertility was significantly related to N and K, with a trend for a relationship with increasing levels of P. In respect to the measured environmental variables this community is intermediate between M4 and S27.
M9 *Carex rostrata-Calliergon cuspidatum* mire	This community is typically dominated by sedges; *C. rostrata, C. diandra, C. lasiocarpa* and *E. angustifolium* but sometimes with much *C. mariscus* or *P. australis*. Usually there is an extensive bryophyte mat, especially *Calliergon* species. The mean species richness of the community was moderate, but there was very great variability (9-47 spp. $4m^{-2}$). Uncommon fen species recorded from this community include *C. limosa, E. gracile, S contortum* and *S. warnstorfii*. This community has strong floristic affinities with *Peuc.-Phrag. caricetosum*.	Though generally found in topogenous mires where it is often a hydroseral community, it is sometimes associated with wet, base-rich flushes. It is essentially a community of low fertility and low base-status situations.
M9a *Campylium stellatum-Scorpidium scorpiodes* sub-community	This sub-community is typically dominated by *C. rostrata* and sometimes *C. lasiocarpa*. *C. diandra* is low common than in M9b. *C. limosa* and *C. echinata* are strongly preferential and there is usually an extensive carpet of "brown" masses. Mean species density was high (26.7 spp. $4m^{-2}$), but with a wide range. PFS and RFS scores were also high, and all three were higher than M9b, although the differences were not significant.	Water level of this community shows great variation but conditions are generally very wet. Found under conditions of moderate to high base status, generally lower than M9b. Conductivity, Mg and Na concentrations were respectively moderate, moderate and low and not significantly different to those of M9b. Mn and Al concentrations were respectively moderate and low and Fe high. All stands examined had very low fertility (significantly lower than M9b and S27). Within the sub-community, substratum fertility was significantly -vly related to base richness and Na concentration, but +vly to N, Fe and Al concentrations.
M9b *Carex diandra-Calliergon giganteum* sub-community	This sub-community is dominated by *C. rostrata* or *C. diandra* and herbaceous associates are more common than in M9a. Usually there is an extensive bryophyte mat, with *C. giganteum* being characteristic. Mean species density and PFS score were borderline moderate/high and RFS score moderate. All three were lower than M9a, although the differences were not significant.	Mean water table level was high and redox potential low, similar to M9a. Water level was lower than S27b, but higher than *Peuc.-Phrag. caricetosum*. but the differences were not statistically significant. Conductivity, Mg and Na concentrations were respectively moderate, moderate and low, though not significantly different from those of M9a. Mean fertility was moderate and significantly greater than that of M9a. Mean fertility was slightly higher (but not significantly) than the mean levels of S27a and S27b. In respect to the measured environmental variables this community occupies an intermediate position with respect to most variables, in particular base status and fertility.
S4 *Phragmites australis* Swamp and reed beds (NB. S4c *Menyanthes trifoliata* and S4d *Atriplex hostata* sub-communities were not sampled)	Stands dominated by *P. australis* are generally species poor, and mean species density, PFS and RFS scores are all very low. Some of the wetter examples contain *Cicuta virosa* and *Sium latifolium*.	Was found under a wide range of conditions and there is little environmental characterisation that can be made. Generally, it is not associated with low water table conditions, though it can persist in dry sites, perhaps if there is periodic flooding.

S4a	*Phragmites* sub-community	Stands dominated by *Phragmites*, ranging from virtual monocultures to examples with a small and variable selection of associates. Mean species density, PFS and RFS scores are very low, but not significantly less than S4b.	Associated with very high water table levels and redox values were very low. Base richness was moderate to very high and it was typically associated with substrata of higher base status than S4b. Mean levels of conductivity and Na respectively were low and moderate. Median values of Fe and Mn were low. Fertility values ranged from very low to very high; low values were associated with high concentrations of toxic metals; median value was high.
S4	*Galium palustre* sub-community	This community has a more open canopy of *Phragmites*, and with a wider range of associates than S4a. Mean species density and PFS scores were low, mean RFS score was moderate. Typically richer than S4a, though the difference was not significant.	Mean water level was moderate, and typically lower than for S4a. Mean conductivity and Na concentration was very high. Fertility was variable, very low to very high.
S5	*Glyceria maxima* swamp Specifically S5b *G. maxima* sub-community	Impoverished vegetation, strongly dominated by *G. maxima*, with a small range of associates, amongst which *Epilobium hirsutum, Filipendula ulmaria, Solanum dulcamara* and *Urtica dioica* are the most characteristic. Species density and PFS score were both considerably very low, with no rare species recorded.	Mean water table levels are low, though the range was from very low to moderate. The mean redox potential value was high. PH, bicarbonate and Ca values showed considerable variation, but mean values were respectively high, very high and extremely high. This vegetation type can occupy a large range of base-richness. Similarly, the range of conductivity and Na values was high, and the mean values are amongst the highest recorded. Mean concentrations of Mn was low, and that of Fe moderate. Mean fertility was high, and was only slightly lower than those of S26. Mean P concentration is very high, but mean N and K concentrations attained only moderate values. The community occupies very fertile, often mineral-rich, substrata in fens.

S24	*Phragmites australis-Peucedanum palustre* fen	Robust fen vegetation, usually dominated by *P. australis* or *C. mariscus*, but occasionally by *Calamagrostis canescens, C. paniculata, G. maxima, J. subnodulosus* or *Phalaris arundinacea* may also be abundant. Associated are a variety of tall herbs. Species density values ranged low - extremely high; mean value moderate, similar to that for S25. Similar range in numbers of principle fen species and rare fen species.	Water level showed a large range from very low to high, but the mean was low, though not significantly below the mean values of S25 or *Peuc-Phrag. caricetosum*. Mean redox value was moderate and significantly below S25 and *Peuc-Phrag. caricetosum*. Low water and low redox can be taken as indicative of summer-dry conditions in sites subject to high water tables for much of the year. Mean Na and conductivity values were respectively very high and extremely high, and Mg values were also high. These reflect oligohaline conditions of Broadland. Mean concentrations of Mn and Fe were moderate. Al was undetectable. Fertility values were variable, but the mean value is moderate, slightly less than that for S25 and significantly greater than for *Peuc.-Phrag. caricetosum*.
S24a	*Carex paniculata* sub-community	Tussock fen with a distinct tall-herb element. Only one example sampled.	Water samples showed conditions broadly typical of the community. No substrate samples could be taken.
S24b	*Glyceria maxima* sub-community	Generally dominated by *G. maxima*, often with *Phragmites*. May contain *Lathyrus palustris* and *Thalictrum flavum*.	Mean water table level was low and a low redox potential. This sub-community was found to be the most fertile of all the S24 sub-communities, not significantly different to S26 and S5.
S24c	*Symphytum offinalis* sub-community	Vegetation with various possible dominants (*Cladium, J. subnodulosus, Phragmites, Phalaris*) but typically with *Molinia* well-developed. *Lathyrus palustris* is frequent and *Symphytum officinale* constant. Mean species density was moderate, PFS and RFS scores were high.	Mean water level was very low and mean redox value was high. Ca concentrations were very high as also were conductivity values. Mean fertility values were low and were reflected in low mean P and K values. Mean fertility was less than S24b, S24d, S24e, S24g, but higher than S24f.
S24d	Typical sub-community	Dominated variously by *Cladium, P. australis, Calamagrostis canescens* and *J. subnodulosus*. Examples with much *Juncus* invariably represent former litter fens, now in varying stages of invasion by bushes and other herbaceous dominants. Similarly compartments with much *Cladium* are sedge beds, some still regularly managed. It is one of the least species-rich examples of the community and has lowe PFS and RFS scores than S24c and S24e.	Habitat conditions show great variability for some variables. Mean water level was low, but significantly higher than S24b and S24c. Base status is generally high, typically higher than S24e, S24f and S24g. Mean conductivity value was extremely high, higher than all the other sub-communities except S24f. Fertility levels are variable. The mean value is the second highest in the community and is comparable with that of the lower fertility sub-communities of S25.

S24e	*Cicuta virosa* sub-community	Dominated by *Cladium* or *Phragmites*, usually with some *Typha angustifolia*. Characteristic associates include *Cicuta virosa*, *Ranunculus lingua* and *Sium latifolium*. Species density and PFS and RFS scores are moderate.	Water levels are invariably high (significantly higher than the other S24 sub-communities) apparently maintained in the way by the vertical mobility of loose peat infill of rafts which it forms over peat pits; this probably largely accounts for the low redox potential. Mean Ca concentration was moderate, though associated with high/very high conductivity HCO_3 and pH values. Mean Ca concentration was the lowest of the S24 sub-communities. Mean fertility was moderate, though the range was wide.
S24f	*Schoenus* sub-community	Typically dominanted by *Schoenus* intermixed with *C. elata* and *J. subnodulosus*. Mean species density and PFS score was borderline low/moderate, while RFS score was moderate/high. This is one of the least species-rich S24 sub-communities.	Mean water level was low and subject to considerable seasonal fluctuation. Redox potential was correspondingly high. Mean water pH was high, but some examples had lower values. Sub-community means of Na concentration and conductivity are both extremely high, with higher values derived from sites over estuarine clays. Fertilities were invariably low.
S24g	*Myrica gale* sub-community	Normally dominated by *Phragmites*, *Cladium* or *Calamagrostis canescens* with *Myrica* and a sparse assemblage of associates.	Only one sample was taken and found to have a very low water table and low substratum pH and fertility was high. Measured environmental variables account for much of the floristic variation in the community, with Ca values and water table height being especially influential.
	Peucedano-Phragmitetum caricetosum	Robust, species-rich fen vegetation mostly dominated by *Cladium*, but occasionally by *Phragmites*. Characterised by species typical of S24 along with *C. diandra*, *C. lasiocarpa*, *Calliergon giganteum* and various *Caricion davallianae* species. Mean species density and for the community very high, ranking the highest of all communities and significantly higher than for S24 and M9. Various rarities are found including *Liparis loeselii*. A number of variants of this type are differentiated.	Mean water level values was moderate, significantly above that of S24, and below M9. Mean redox potential was high, significantly higher than the mean for S24. Mean pH and HCO_3 concentration were high, higher than M9, but similar to S24. Mean Ca concentration was also high. The community is confined to freshwater situations. The community has lowest mean fertility for rich fen communities.
	Peucedano-Phragmitetum caricetosum typicum	Stands of this variant were significantly less species-rich and had lower PFS scores than the other two variants. They did not support such notable species as *Liparis loeselii*.	The mean water table was significantly lower than that of the other variants and fertility values were also somewhat higher than the other variants.
	Peucedano-Phragmitetum caricetosum-Ranunculus lingua var.	Species-rich fen vegetation, richer than the *typicum* variant, but not significantly different from the *Molinia* variant.	Wetter than the *typicum* variant, but not significantly different from the *Molinia* variant. Fertility is very low.
	Peucedano-Phragmitetum caricetosum-Molinia var.	Species-rich vegetation, mostly dominated by *Chadium*, which is, in some instances at least, a seral development from *R. lingua* var. It is also floristically and serally transitional to S24f.	Water levels recorded were similar to *Ranunculus lingua* variant.
S25	*Phragmites australis-Eupatorium cannabinum* fen	Rather variable but robust, 'mixed fen' vegetation, typically dominated by tall herbaceous monocotyledons such as *Cladium* or *C. paniculata*, but most usually by *Phragmites* and accompanied by a range of tall herbaceous dicotyledons. The community has moderate mean species density, PFS and RFS scores were respectively low and very low, the latter emphasising the infrequency of less common species in this vegetation. The community mean value for species density was not significantly lower than S24, but there were significantly fewer rare species, helping to distinguish the two communities.	Water levels were found to be borderline low/moderate. pH and Ca substrate values were high, slightly above S24. Mean conductivity was very high but mean Na concentration was low. Mean fertility value was fairly high, but not significantly higher than S24.
S25a	*Phragmites australis* sub-community	Mostly dominated by *Phragmites*. Mean species diversity was moderate and PFS and RFS scores were respectively low and very low.	Mean water levels was moderate. Mean pH and Ca values were high and extremely high respectively. Fertility mean was borderline moderate/high and slightly below S25b.
S25b	*Carex paniculata* sub-community	Floristically similar to S25a, but dominated by *Carex paniculata*. Tall herbaceous dicotyledons provide most of the associates low diversity vegetation and with a PFS score higher than S25a.	Water levels were variable, though less so than S25a. Base richness was high/very high. Fertility-low-very high, but with a high community mean.

S25c	*Cladium mariscus* sub-community NB. only 2 samples studied)	Strongly dominated by *Cladium* and *Phragmites* (low-moderate species richness.	The community is closely related to S24 in terms of base status, but clearly differentiated in terms of ionic strength. The measured environmental variables do not account for all the main variation in species composition they do relate to underlying trends. pH, HCO_3 and ionic strength are most influential.
S26	*Phragmites australis-Urtica dioica* fen	Very variable tall-herb fen vegetation, usually with abundant *Phragmites* and *U. dioica*. Only 5 examples were recorded therefore any relationship found should be regarded as tentative. Mean species-richness was low and mean PFS and RFS scores were very low/low.	Water levels were variable, very low-moderate. There was a significant negative relationship to species density, PFS and RFS scores. It is often found in very base rich sites of high-very high fertility and fertility is sometimes reflected by P values.
S26a	*Filipendula ulmaria* sub-community	Tall dense vegetation dominated by *Phragmites*, *Urtica* or *Filipendula*.	Habitat conditions were mostly similar to those described for the 'Association'.
S27	*Carex rostrata-Potentilla palustris* fen	A variable community which may be dominated by *Carex rostrata*, *C. nigra*, *C. elata*, *Menyanthes trifoliata*, *Potentilla palustris* and with contribution from *Calliergon* mosses. It has moderate species richness, though the mean value is much less than that for M9, but not significantly different from S24, S25 and M22. It has moderate/low PFS and RFS scores.	Mean water level was high, with highest levels associated with a reduction in species density, reflecting the transition to swamp communities. The community is found in situations of intermediate base status with respect to the main rich and poor fen communities. Mean fertility is moderate, higher than that of M9 and not significantly different to that of S24 or M22. There was a significant positive relationship between fertility and N and P concentrations. Analysis showed that although the measured environmental variables do not account for the main variation in species composition they do relate to an underlying trend.
S27a	*Carex rostrata-Equisetum fluviatile* sub-community	Generally dominated by *C. rostrata* (sometimes *C. aquatalis* or *C. vesicaria*) with *E. fluviatile*, *P. palustris* and *M. trifoliata*. Mean species density, PFS and RFS scores slightly lower than S27b.	Water levels are high and base-richness is significantly lower than for S27b, though there is considerable variability.
S27b	*Lysimachia vulgaris* sub-community	Characterised by the occurrence of tall herbs eg *L. vulgaris*, *E. cannabinum*. *Phragmites* is often important, sometimes *C. mariscus* can occur.	Generally found in situations of higher base richness and fertility than S27a.
S27c	Provisional *C. aquatalis* sub community	Includes samples which clearly belong to S27, but which are dominated by *C. aquatalis*. Mean species density low, though in range of S27a, indicating transition to species-poor swamp.	Typically with a high water table and rather less base rich conditions than the other sub-communities. But the substrate may be fertile, similar values to those of S25.

Betula-Dryopteridetum cristatae placed within W2 *Salix cinerea-Betula pubescens-Phragmites australis*, though the optimal development of the community is with few trees.	This community represents hydroseral development of poor fen from rich fen in Broadland and is characterised by *Sphagnum* species, *Drosera rotundifolia* and *Dryopteris cristata* often with a degree of *Salix* and *Betula* invasion. Species density was high PFS and RFS scores were moderate.	The water table is generally at or near the surface because the vegetation generally forms floating rafts. Water chemical data may be uninformative about the community which shows a strong gradient with a (usually narrow) horizon of *Sphagnum* peat perched over base-rich water.