Controls on the Composition of Vegetation of Valley-head Fens in the Oxford region

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Summary

The environmental conditions associated with the occurrence of two of the main plant communities (M13, black bog-rush - blunt-flowered rush, *Schoenus nigricans – Juncus subnodulosus* mire and M22 blunt-flowered rush – marsh thistle, *Juncus subnodulosus-Cirsium palustre* fen meadow) of valley-head fens in the Oxford region are compared, using data from the Oxford region and from eastern England. Both communities occur in similar topographical circumstances and can be associated with comparable water tables and base richness, but examples of M13 are consistently found in less fertile conditions than M22. Low fertility appears to be a consequence of three factors: low phosphate concentrations associated with a P-deficient groundwater supply, immobilisation of P by adsorption upon calcite precipitates and a low fertility substratum (often sands and gravels). M13 vegetation is largely confined to fens fed by chalk or limestone aquifers, and is associated with consistently high summer water tables. M22 vegetation also occurs in fens fed from chalk or limestone, but it is then typically associated with lower summer water tables and with less permeable and more fertile substrata. Valley-head fens in this region that are fed primarily from drift aquifers do not support M13 vegetation but M22 communities occur both in locations with consistently high summer water tables and with lower water levels. The drift-fed permanent seepages that support M22 vegetation are more fertile than comparable chalk or limestone-fed permanent seepages with M13 vegetation. The conjunction of conditions which favour M13 vegetation (strong chalk or limestone springs, permeable and low fertility substrata) is uncommon and probably largely accounts for the localisation and scarcity of this community.

Introduction

The fens of the Cothill basin have long been recognised as having great botanical value, on account both of their fen woodland and herbaceous fen communities (Tansley 1939; Clapham 1940). Species records from Cothill Fen, Frilford Heath, Barrow Farm Fen, Wootton (Lashford Lane) Fen and Bullingdon Bog (Lye Valley), amongst other sites, (Bowen 1968; Killick *et al* 1998) demonstrate the botanical importance of these fens. Elsewhere in the Oxford region, in Oxfordshire (Fojt 1983) and, particularly, in Buckinghamshire (Wheeler 1983, 1997) there is a number of other valley-head[1] fens, developed in comparable topographical and hydrological situations to those of the Cothill Basin, but these are much less well known and documented, and are less distinguished floristically.

The floristic interest of the fens of the Cothill Basin relates particularly to the occurrence of examples of a rare and species-rich vegetation type which is referable to

[1] The term 'valley-head fen' was used by Fojt (1990) to refer to (usually small) wetlands fed by springs or seepages, normally located at or near the headwaters of small stream valleys. The term encompasses many wetlands that have often been described as 'valley fens' (*e.g.* Tansley, 1939) and is preferred to 'valley fen' because this latter term has been used in many different ways. For example Heathwaite & Göttlich (1993) use the 'valley fen' to refer to four quite different hydrotopographical wetland types and Haslam (1965) uses 'valley fen' specifically to refer to fens of small floodplains, rather than spring-fed wetlands (which she terms 'headwater fens'), which is almost the opposite to the usage of Tansley (1939).

the M13 black bog-rush - blunt-flowered rush mire of Rodwell (1991). This community does not occur in most of the other valley-head systems in the region; instead, the main herbaceous vegetation of the valley-head fens in Buckinghamshire, and in north Oxfordshire, is a form of fen meadow, dominated often by lesser pond-sedge (*Carex acutiformis)* or blunt-flowered rush (*Juncus subnodulosus)*, and referable to the M22 blunt-flowered rush – marsh thistle fen meadow of Rodwell (1991).

The reasons for the localisation of M13 fen to a handful of distinctive sites, and its replacement by M22 fen meadow in comparable valley-head fen sites elsewhere in the Oxford region, are not intuitively obvious. In this paper a comparison will be made between the conditions associated with the occurrence of M13 black bog-rush - blunt-flowered rush fen and those associated with M22 blunt-flowered rush – marsh thistle fen meadow to help identify the particular factors that appear to be necessary for the development of species-rich M13 fen.

Methods

The material synthesised here is derived from four main sources: (a) a survey of fen vegetation in England and Wales (Wheeler 1980a, b, c); (b) examination of the floristic and environmental characteristics of valley-head fens in Buckinghamshire (Wheeler, 1983); (c) a survey of habitat conditions associated with different types of fen vegetation in Britain (Wheeler & Shaw 1987); and (d) an analysis of the occurrence of specific types of fen vegetation in eastern England in relation to environmental conditions and water supply mechanisms (Wheeler & Shaw 2001). Details of methods are provided in the publications cited. In this study, these data sets have been analysed by generic comparisons of samples of M13 and M22 communities from a range of sites in eastern England and by specific comparison of data from Clack Fen, a M22 valley-head fen in north Buckinghamshire (Wheeler 1983) with data from stands of M13 vegetation at Cothill Fen (Parsonage Moor).

Results

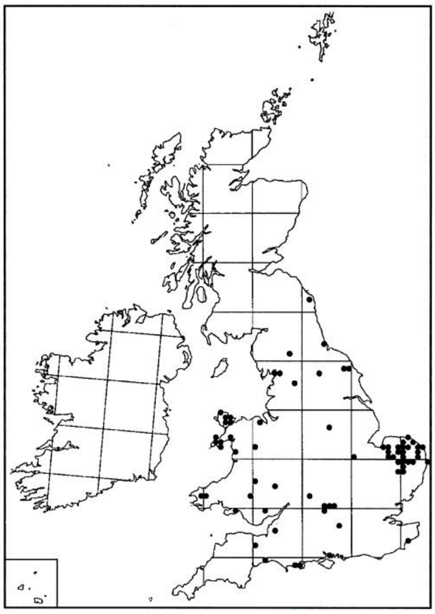
Vegetation Types

Although a range of vegetation types occur in the valley-head fens of Oxfordshire and adjoining regions (Fojt, 1983; Wheeler, 1983), attention will be focussed exclusively on a comparison between two herbaceous types: M13 black bog-rush - blunt-flowered rush mire and M22 blunt-flowered rush – marsh thistle fen meadow.

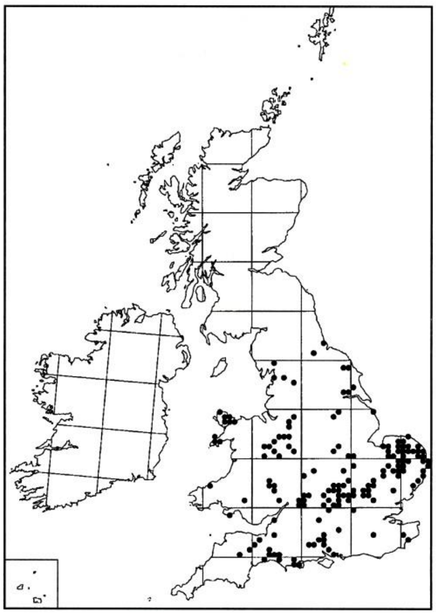
M13 black bog-rush - blunt-flowered rush mire is generally allocated to the Caricion davallianae alliance. Black bog-rush and blunt-flowered rush are usually the dominant species, with a wide range of associates, including a number of uncommon species (e.g. narrow-leaved marsh-orchid (*Dactylorhiza traunsteineri*), broad-leaved cottongrass (*Eriophorum latifolium*), common butterwort *(Pinguicula vulgaris*). The rarity and richness of this community means that examples are usually considered to have high conservation value and many sites supporting this vegetation are potential Special Areas of Conservation, designated under the EC Directive on the Conservation of Natural Habitats and Wild Fauna and Flora[2], as implemented in Great Britain. The main centres for this community in Britain are in eastern England (mainly Norfolk) and Anglesey (figure 1), but good examples also occur in the Oxford region, specifically at Barrow Farm Fen, Bullingdon Bog (Lye Valley),

[2] Directive 92/43/EEC, amended by Directive 97/62/EC

Cothill Fen and Frilford Heath. This vegetation was also once well developed at Wootton Fen (Lashford Lane Fen) and Sydlings Copse, but only degraded remnants now occur at these sites. The community is not now known from Buckinghamshire: Druce (1926) refers to a site near Winslow which seems to have been an example of M13 fen, but this no longer appears to be extant.



M13: *Schoenus nigricans – Juncus subnodulosus* mire.



M22: *Juncus subnodulosus – Cirsium palustre* fen-meadow

Figure 1. Distribution of M13 black bog-rush - blunt-flowered rush mire and M22 blunt-flowered rush – marsh thistle fen meadow in England and Wales.

M22 blunt-flowered rush – marsh thistle fen meadow is generally allocated to the Calthion alliance. Typical dominants are blunt-flowered rush (*Juncus subnodulosus),* lesser pond-sedge *(Carex acutiformis)* and brown sedge, *(Carex disticha).* It is probably the most widespread plant community of base-rich fens in England and Wales (figure 1), and is found in a much wider range of situations than M13, encompassing both rather dry and permanently wet sites. Some examples occur on floodplains, in ecohydrological conditions that contrast strongly with those that support M13 fen, but others occur in association with springs and seepage areas that appear comparable with those characteristic of M13 fen. Examples of this community do not have international importance and many sites supporting it are not Sites of Special Scientific Interest.

Black bog-rush - blunt-flowered rush mire is typically considerably more species rich than blunt-flowered rush – marsh thistle fen meadow fen meadow, particularly with respect to species labelled as rare in table 1. Species that are particularly characteristic of M13 fen and which help separate it from fen meadow, are listed in table 2.

Table 1: Species richness of samples of black bog-rush - blunt-flowered rush mire (M13) and blunt-flowered rush – marsh thistle fen meadow (M22) in eastern England. Mean, minimum and maximum number of species per 2mx2m sample. Rare species are defined by Wheeler (1988).

		All Species			Rare Species		
	n	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**
M13	39	26.8	9	65	1.95	0	13
M22	80	18.6	3	66	0.38	0	7

Table 2: Plant species characteristic of M13 black bog-rush - blunt-flowered rush mire in the Oxford region and not found in M22 fen meadow.

Angiosperms		Bryophytes
Anagallis tenella	bog pimpernel	*Aneura pinguis*
Carex hostiana	tawny sedge	*Bryum pseudotriquetrum*
Carex pulicaris	flea sedge	*Campylium elodes*
Carex viridula	yellow sedge	*Campylium stellatum*
Dactylorhiza incarnata	early marsh orchid	*Cratoneuron commutatum*
Dactylorhiza praetermissa	southern marsh orchid	*Drepanocladus revolvens (s.l.)*
Dactylorhiza traunsteineri	narrow-leaved marsh orchid	*Fissidens adianthoides*
Eleocharis quinqueflora	few-flowered spike rush	*Pellia endiviifolia*
Epipactis palustris	marsh helleborine	*Philonotis calcarea*
Eriophorum latifolium	broad-leaved cotton grass	*Philonotis fontana*
Gymnadenia conopsea	fragrant orchid	*Plagiomnium elatum*
Listera ovata	twayblade	*Preissia quadrata*
Parnassia palustris	grass of Parnassus	*Rhizomnium pseudopunctatum*
Pedicularis palustris	marsh lousewort	*Riccardia chamedryfolia*
Pinguicula vulgaris	butterwort	*Riccardia multifida*
Potamogeton coloratus	fen pondweed	
Schoenus nigricans	black bog rush	

Habitat Conditions

The species composition of wetland vegetation is controlled by four main suites of variables (Wheeler & Proctor 2000): location (phytogeography, latitude and altitude); water regime (water levels and water movement); hydrochemical conditions (especially base status and fertility, but also the availability of toxic ions such as Fe^{2+}, Mn^{2+} and S^{-}); and management and succession. Differences between M13 and M22 sites within eastern England are unlikely to reflect phytogeographical differences, nor do they appear to be a product of different management regimes (examples of both communities are regularly grazed), so it is probable that differences are either hydrological or hydrochemical in origin.

Summer Water Tables

Overall, there is a tendency for M22 stands to occur in somewhat drier conditions than M13 stands (table 3). However, it is not difficult to find examples of M22 that are just as summer-wet as examples of M13, as is seen in the comparison between Cothill Fen (M13) and Clack Fen (M22). Despite the overall trend, this suggests that differences in summer water tables are not critical to determining the occurrence of these two community types.

Table 3: Summer Water Tables associated with stands of *Schoeno-Juncetum* (M13) and fen meadow (M22) in eastern England

	Number of samples	Mean water table (cm)	SD	Min	Max
M13	39	-9.5	12.4	-38.6	5
M22	80	-21.1	36.5	-175	0.4
Cothill (M13)		-0.8			
Clack (M22)		-1.1			

Wetland Water Supply Mechanisms

Wheeler and Shaw (2001) identified nine main types of water supply mechanisms in wetlands of eastern England. The distribution of vegetation type in relation to these is summarised in table 4. Most *Schoeno-Juncetum* stands were recorded from Permanent Seepage Fens (*i.e.* wetlands, typically sloping, fed by 'permanent' springs or seepages and with the water table permanently close to the surface, *i.e.* water visible or oozing underfoot). By contrast, most examples of M22 fen meadow were recorded from Intermittent Seepage Fens (*i.e.* wetlands fed by intermittent springs and seepages, or where the groundwater table is always shallowly subsurface). However, as is the case with summer water table, there is significant overlap between the two communities: a small number of M13 fens were recorded from Intermittent Seepages and, more importantly, a number of M22 fen meadow stands occupied Permanent Seepages. This suggests that difference in water supply mechanism does not provide a critical generic distinction between these two vegetation types.

Table 4: Occurrence of *Schoeno-Juncetum* (M13) and fen meadow (M22) stands in different wetland types in eastern England. WETMEC = 'Water Supply Mechanism', defined by Wheeler & Shaw (2001). S-J species are species particularly characteristic of M13 (table 2).

	Schoeno-Juncetum M13		Rush Fen Meadow M22	
Water supply mechanism	Number of samples	Mean number of S-J spp.	Number of samples	Mean number of S-J spp.
1. Permanent Seepage Slope	**28**	**13.9**	16	2.3
2. Intermittent Seepage	6	6.4	**43**	**1.8**
4. Percolating Seepage Basin			8	0.8
5. Subsurface Percolating Seepage Basin	2	8	4	3.8
7. Summer 'Dry' Floodplains and Basins			6	2.5
8. Valley Bottom Wetlands			3	0

Base richness

Base-richness, as reflected in calcium concentration, alkalinity and pH, might appear to be a likely distinguishing feature of M13 fen as Clapham (1940) specifically referred to the M13 fens of the Cothill basin as being "calcareous" fens and Wheeler (1980b) also allocated M13 vegetation to the broad category of "calcareous mires". This denomination may largely reflect the milky appearance of the water in some M13 fens, caused by suspended particles of calcite (calcium carbonate) (similar marly suspensions, or concretions of tufa, rarely occur in examples of M22 fen meadow) (Boyer & Wheeler 1989). However, there is little generic difference in measured water pH and alkalinity, and in soil calcium concentration, between stands of M13 and M22 vegetation in spring-fed fens in eastern England (table 5). Indeed determinations of water alkalinity and soil Ca concentration point to higher values at Clack Fen (with no marly material) than at Cothill Fen (with some marl) (table 5). This suggests that sites supporting M13 are not necessarily intrinsically more 'calcareous', in terms of the chemistry of the rooting zone, than are sites supporting M22. Nonetheless, almost all sites supporting M13 vegetation in eastern England are fed by groundwater derived primarily from a chalk or limestone aquifer whereas examples of M22 have a wider range of groundwater provenance (though many are also fed by water from chalk or oolitic limestone) (table 6).

Table 5: Base-richness and fertility associated with *Schoeno-Juncetum* (M13) and fen meadow (M22) stands in eastern England. Fertility was estimated phytometrically by growth of a test species, reed canary-grass (*Phalaris arundinacea*), on soil samples in standard conditions. Soil Ca concentration was determined on ammonium acetate extracts of fresh soils.

	n	Water pH mean	Alkalinity (mg l^{-1}) mean	Soil Ca mg (l_{soil}^{-1}) mean	Fertility (mg $plant^{-1}$)
M13	39	6.8	419	2420	7.4
M22	80	6.7	404	2283	13.6
Cothill (M13)		7.4	439	2194	4.36
Clack (M22)		7.2	480	2847	23.6

Table 6: Main aquifer supplying groundwater-fed stands of *Schoeno-Juncetum* (M13) and fen meadow (M22) in eastern England. Values are percentage occurrence (*n* = 119).

***Schoeno-Juncetum* (M13)**

Chalk	Chalk / Drift	Chalk/Crag	Crag/Drift	Oolites	Drift
70%	5%	15%	5%	5%	0%

Fen meadow (M22)

Chalk		Chalk/Crag	Crag	Oolites	Drift
53%		5%	5%	7%	30%

Fertility

The greatest, and most consistent, difference between examples of M22 fen meadow and M13 fen is that the latter invariably occupies low fertility (oligotrophic) soils whilst M22 occurs in more fertile (mesotrophic or eutrophic) conditions (table 5). This difference is reflected in rates of above-ground productivity (Wheeler & Shaw 1991). It does not seem to be related, generically, to the nature of adjoining land use: both M13 fens and examples of M22 fen meadow sometimes occur in locations adjoined by intensive arable farming. However, M13 fens appear to be consistently more deficient in plant-available phosphorus than M22 fens (Boyer & Wheeler 1989) and this appears to be related to the provenance of their main groundwater supply. The chalk and limestone aquifers that provide the groundwater supply to almost all examples of M13 fen in eastern England tend to be intrinsically deficient in phosphorus. Moreover, there is some evidence that the precipitation of calcite (marl) which is observed at the surface of many M13 fens is associated with the co-precipitation (adsorption) of phosphorus (Boyer & Wheeler 1989). Calcite precipitation occurs because the partial pressure of CO_2 in a carbonate aquifer is higher (*c.* 10^{-2} atm.) than its atmospheric partial pressure (*c.* $10^{-3.5}$ atm.). As carbonate-rich groundwater emerges, degassing of CO_2 occurs accompanied by precipitation of calcite (as marl or tufa) and by co-precipitation of phosphorus as phosphate:

$$Ca^{2+} + 2HCO_3^- \Im CaCO_3\downarrow + CO_2\uparrow + H_2O$$

This process is not specifically confined to a chalk or limestone aquifer – it could, in principle, also occur in groundwater discharge from a highly calcareous drift – but in eastern England it appears to be mainly associated with a chalk or limestone groundwater supply.

These results suggest that the occurrence of M13 fen is dependent upon a supply of highly calcareous groundwater, but not specifically because of the high calcium concentrations *per se*, but on account of associated phosphorus deficiency.

Interaction with the substratum

Whilst the occurrence of low-productivity M13 vegetation can be explained by processes associated with discharge of chalk or limestone groundwater, it is evident that numerous stands of the more productive M22 vegetation are also irrigated from these same aquifers. Stands of M22 vegetation fed primarily by chalk water are found in situations that are, on average, twice as fertile as those supporting M13, even though the water source is thought to be the same (table 7). One explanation for this is that intrinsic properties of the substrata also determine the fertility of the fens, in addition to water source, and that these differ between M13 and M22 stands. In chalk-water-fed sites, the substratum of M22 stands appears to have some different properties to that associated with M13 (table 7). In general, M22 communities occur where the top layer of the substratum is rich in silts and clays, whereas M13 stands are more often associated with sands and gravels. The more silty soils appear to have higher intrinsic fertilities than do sands and gravels, and this may account for the occurrence of a relatively productive fen vegetation irrespective of the impoverished characteristics of the chalk-water supply. Another difference is that, in chalk-water-fed sites, stands of M22 vegetation generally occur in more summer-dry locations than M13 (table 7). It is possible – though by no means certain – that the lower permeabilities of silt and clay rich substrata may account, in at least some cases, for the lower summer water tables associated with M22 stands, because of increased resistance to groundwater flow.

Table 7: Water table, fertility (± SD) and estimated soil permeability associated with stands of M13 and M22 thought to be irrigated primarily by chalk water. Mean water table is expressed relative to the surface (zero datum) (± SD). Fertility was estimated phytometrically by growth of a test species, reed canary-grass (*Phalaris arundinacea*), on soil samples in standard conditions. Permeability to water in the main rooting zone was estimated as categories on a 7-point scale (1= least permeable, 7 = most permeable) based on the composition of the material

NVC	*n*	Mean water table (cm)	± SD	Mean fertility (mg plant^{-1})	± SD	Permeability (category)
M13	39	-7.75	11.12	6.7	4.18	4.4
M22	80	-16.05	13.96	13.8	5.41	3.4

Similar controls to those suggested to explain the occurrence of M13 *versus* M22 in chalk-water-fed sites may also help explain variation in the quality and composition of examples of M13 vegetation. Examples of M13 vegetation on less permeable soils tend to be associated with lower summer water tables, higher fertilities, and fewer typical M13 species, than do examples on sands and gravels (table 8).

Table 8: Permeability of the top layer of substratum, summer water table and fertility in relation to characteristics of *Schoeno-Juncetum* (M13) stands. Water table is expressed relative to the surface (zero datum). Fertility was estimated phytometrically by growth of a test species, reed canary-grass (*Phalaris arundinacea*), on soil samples in standard conditions. Permeability in the main rooting zone was estimated as categories on a 7-point scale (1= least permeable, 7 = most permeable) based on the composition of the material. M13 characteristic species are identified in table 2.

Top–layer Permeability Category	*n*	Mean Summer Water Table (cm)	Mean Fertility (mg)	Mean number of M13 Characteristic Species (spp. 4m^{-2})
1	0			
2	2	-82.0	9	9.0
3	9	-17.1	9.2	9.5
4	13	-9.1	8	11.4
5	9	-5.5	5	12.7
6	64	-3.2	4	14.7
7	0			

Discussion

Conditions associated with the occurrence of *Schoeno-Juncetum* (M13) vegetation

Although there is some overlap, it is possible to identify combinations of conditions that favour the development of M13 and M22 vegetation types in groundwater-fed fens.

In valley-head fens fed primarily from a chalk or limestone aquifer, M13 vegetation typically occurs where the water table is consistently high and where the rooting substratum is of low fertility (sand or gravel). Where the rooting substratum is mesotrophic (usually because it contains silt or clay) then M22 vegetation develops, even though the primary water supply is from chalk or limestone (figure 2). A complicating factor is that the silt-rich chalk-water fed stands tend also to have lower summer waters as well as being more fertile and it cannot be determined from the available data which of these variables is most critical to the character of the vegetation.

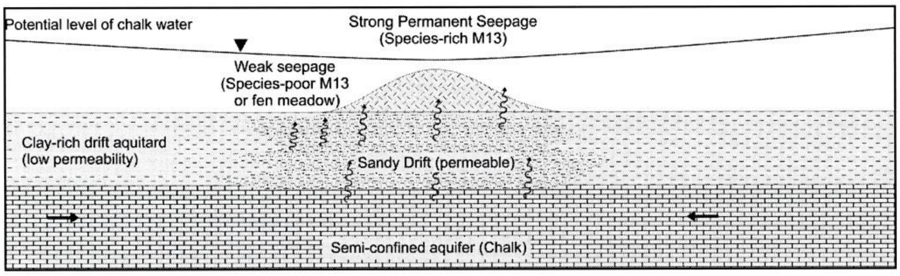


Fig 2. Diagrammatic section across a spring mound in a valley-head fen fed by strongly artesian groundwater from a chalk aquifer semi-confined by boulder clay.

In valley-head fens which are fed from a drift aquifer the rooting substratum is invariably mesotrophic, at least in Oxfordshire and Buckinghamshire, even when the top-layer is composed of sands and gravels. In this situation fen meadow (M22) vegetation occurs both in permanently wet and in more summer-dry locations. As is the case with chalk-water-fed sites, the drier locations often also have clay or silt-rich substrata.

Thus the primary difference between sites supporting M13 and M22 communities appears not to be due to water regime or base-richness, but to the fertility of the rooting zone. This is a product of the character and composition of the substratum and the groundwater supply, and of associated hydrochemical processes.

A further consideration is that the substratum of examples of M22 vegetation fed by springs from a drift aquifer is often rich in precipitated ochre (hydrated iron oxides) (Wheeler *et al.* 1985) and this provides an additional chemical difference from stands fed by chalk and limestone water which may possibly influence the composition of the fen vegetation. There is experimental evidence that high concentrations of iron are selectively toxic to some of the rarer plant species of fens (Snowden & Wheeler 1993), but the rôle, if any, of iron in determining the composition of valley-head fen vegetation remains uncertain.

Variation in the quality of M13 vegetation also appears to be related to water table, the 'strength' of groundwater supply and the fertility of the substratum. The most species-rich examples of this community occur in locations with a strong supply (often strongly artesian) of chalk or limestone water and a low-fertility substratum (often sands or gravels) (Wheeler & Shaw 2001). Such conditions are frequently interdependent. For example, where lenses of sands and gravels connect the fen surface to an artesian aquifer (figure 2) they help to provide both good hydraulic connectivity and low fertility. Such conjunctions of conditions tend to be unusual, and are almost geological 'anomalies', and examples of M13 fen – particularly species-rich examples – are correspondingly uncommon.

This analysis suggests that the strong localisation of M13 fen is primarily determined by the scarcity of appropriate hydrogeological conditions in which it can develop. Although some examples of this vegetation have undoubtedly been destroyed by drainage and groundwater abstraction, there is no reason to suspect that this community was formerly very much more widespread than it is now. For example, in Norfolk 'good' examples of M13 fen were scarce even in the 19th century. Interestingly, many of these still exist, though sometimes partly degraded (Wheeler, 1999).

Vulnerability of *Schoeno-Juncetum* (M13) stands to dehydration and enrichment

The requirement of M13 fen for consistently high water tables and low fertility conditions may lead to the expectation that this vegetation is particularly vulnerable to changes, such as groundwater abstraction, drainage and agricultural enrichment. Many examples of M13 fen are quite closely associated with boreholes and are potentially vulnerable to groundwater abstraction (Fojt, 1994), although damage has only been demonstrated conclusively in a few examples, most notably Redgrave Fen (Harding, 1993). More examples appear to have been damaged by drainage, though again most evidence for this is anecdotal. However, some stands of M13 fen – especially the richest examples associated with strong artesian water supply – may be partly buffered against hydrological changes (Wheeler & Shaw, 2001). Thus, although dependent on consistently high water tables, some M13 sites may have been less impacted by drainage and groundwater abstraction than have some other wetlands supplied by less strong springs and seepages, and this may well account for the persistence of some examples of this vegetation.

Although oligotrophic in character, stands of M13 fen appear to have been able to co-exist with high intensity arable farming in their catchment, apparently because their main water supply is phosphate deficient, and/or because of phosphorus immobilisation by natural geochemical processes (Boyer & Wheeler 1989). Moreover, because these fens appear to be primarily phosphorus-limited, they seem to show little response to nitrate enrichment from agricultural sources. No examples appear to be known of M13 fens which have been badly damaged by agricultural enrichment, though this may just reflect lack of relevant information. It is also not known whether such low-productivity fens can co-exist with intensive agriculture in perpetuity.

A further benefit of the low fertility of M13 fens is that dereliction processes, induced by lack of vegetation management, for example mowing or grazing, are slower than in more fertile wetlands, and rates of species loss are corresponding lower. In consequence, M13 fens may be less affected by short-term dereliction than are some other wetland types. Nonetheless, when dereliction is sustained most of the characteristic *Schoeno-Juncetum* species may be lost, and Wheeler (1999) provides some evidence that dereliction has been an important cause of damage to some M13 fen sites in Norfolk.

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