

FEN PLANT COMMUNITIES OF BROADLAND

**Results of a Comprehensive Survey 2005-2009
November 2010**



**Undertaken on behalf of the Broads Authority and
Natural England**

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Front cover: British White cattle on Crostwick Marshes

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SUMMARY

Together with a survey of fen invertebrates, the Broads Authority and Natural England commissioned a comprehensive survey of the herbaceous fen vegetation of Broadland. The main fieldwork was undertaken in 2007-2009, with pilot survey work from 2005 added to the data set. The field methods of the National Vegetation Classification (NVC) were adopted. In total 7038 samples of vegetation were recorded in approximately 1750ha of fen, equating to one sample per 0.25ha.

The *Results* section and Appendix I describe the floristics of all of the vegetation types identified in the survey and their matching with reference NVC types. Five entirely new communities are proposed, dominated mostly by one of *Carex acutiformis*, *Carex riparia* or *Calamagrostis canescens*. Most notable is the BS5 *Dryopteris cristata*-*Sphagnum* spp fen, a mixed mire of high conservation importance. In addition, five new sub-communities of S4 *Phragmites australis* reedbed are identified, five new variants of established S4 sub-communities, and three new sub-communities of S26 *Phragmites-Urtica* fen plus a new variant of an established sub-community. Three rather minor variants of the Typical sub-community of M22 *Juncus-Cirsium* fen meadow are also distinguished.

The *Overview of Fen Communities* section summarises aspects of the plant ecology of the vegetation types, and their relationship to environmental and management factors. The different vegetation types are placed in the context of the hydrosere. The findings of this survey are discussed together with those of previous workers, most notably Pallis, Lambert, Wheeler and Parmenter.

In Section 5, the *Conservation Importance* of the fens is described. The distribution of the four Annex I Habitats Directive habitats is mapped for the whole of Broadland. The *Calcareous fens with Cladium mariscus* feature is the most extensive. Nationally and internationally this is very rare, being designated in only 13 SACs in the UK. The Broads holds a very substantial area of this resource, principally in the Ant and Thurne, and to a lesser extent the Bure. The section also describes unique fen types. These include S24 *Phragmites-Peucedanum* fen and the newly proposed BS5 *Dryopteris cristata*-*Sphagnum* spp sub-community. Another very special community, *Peucedano-Phragmitetum caricetosum* (Wheeler 1980a) is very species rich, supports a wide range of rare species and is restricted to turf ponds in the Ant and Bure. It was not recorded during this survey, most probably because of habitat change. Its recovery is a conservation concern. The extent of these and all of the major plant communities in Broadland is described.

Other important attributes of conservation value are discussed. These include the very complex physical structure of the fens from the micro- to the habitat scale, and the value added by the juxtaposition of fens with marshes, open water and woodland. An index of diversity is used to map the richness of plant communities. The Ant catchment has the most diverse fens, followed by the Bure. The Thurne, Yare and Waveney fens are generally less rich in fen species although there are notable exceptions, and their fens have other values, such as the extensive stands of *Cladium* vegetation in the Thurne.

A running theme through this report is *Change in the Fens* (Section 6), summarised as:

- An expansion of eutrophic fens.
- An expansion of fens dominated by *Carex riparia* and/or *Carex acutiformis*.

- An increase in *Phragmites australis*, so that it is ubiquitous in almost all fen, swamp and mire communities. Reed-based fen appears to have succeeded a variety of communities including *Cladium* and *Glyceria*.
- A probable increase in the extent and range in communities showing a brackish water influence.
- A decrease in *Glyceria maxima* communities, especially in the Yare, where there appears to have been wholesale change in much of the valley floodplain.
- A reduction in the extent and quality of S24 tall herb fens, partly as a consequence of the expansion of the above vegetation types.
- The truncation of the hydrosere, with the loss of much of the aquatic and pioneer swamp phases, the early secondary swamp communities such as *Carex paniculata* fen and the dryland to floodplain transition mires and fens.
- Autogenic change within fen communities through growth of the peat surface, the succession to drier fen types and the accumulation of surface nutrients.
- A loss of all fen types to scrub and woodland over-growth including the middle hydrosere floodplain tall herb fens.
- Probable loss of structural diversity of the fens consequent upon the above changes.

These conclusions are based on a range of evidence, much of which is circumstantial but are corroborated by known environmental changes in the Broads, which include the cessation of management, eutrophication of Broadland waters, changes to flow regimes in some rivers and an increase in catchment salinity. While the detail of change is uncertain, the above conclusions are robust in terms of the general direction of change and the overall impact on the fens.

The potential impacts of climate change are outlined. The broad predictions need to be translated more precisely into likely change within the fen compartments, something which requires additional research.

Other *Issues Requiring New Research* are outlined in Section 7. These include:

- Identifying direct evidence of vegetation change, and linking this to changes in environmental factors.
- Improving our understanding of climate change.
- Improving our understanding of fen management and how different management techniques can assist in arresting change and restoring degraded fen types.
- How the vegetation types relate to the national reference communities in the NVC.

In Section 8, the ways in which the vegetation data set can be further developed are discussed. These include:

- Surveillance and monitoring of the fen resource. The importance of monitoring is discussed and some strategies outlined. The fen survey is shown to be central to any new monitoring strategy, including for climate change.
- Linking the vegetation survey through digital GIS to other environmental data sets including elevation, hydrology, water quality, soils, the historic environment, monitoring, other biodiversity data and site management information.
- Using the vegetation data to develop remote sensing techniques for the Broads and nationally, providing cost effective inventory and surveillance monitoring.
- The survey data are shown to be central to the development of key environmental strategies for the management of the fen resource.

In the *Conclusion*, the report suggests that in order to address the various fen conservation issues highlighted by the survey, the following will be required:

- The restoration of the full hydrosere, and in particular the re-establishment of pioneer swamp vegetation at the broad margins.
- The removal of further areas of scrub in areas of critical fen interest and in locations which would restore key parts of the hydrosere.
- Extension of both grazing and cutting to include all of the herbaceous fen resource.
- The continuation of the programme of shallow turf ponding, with the cyclical excavation of peat to a depth of 70cm.
- Ensuring the fen resource is protected against the impacts of climate change. This includes the creation of new fen areas to compensate for the inevitable losses and an adaptation strategy to conserve existing fens.

Achieving these aspirations requires a step change in the management of the fens. The report suggests that a new rural industry, based on economically sustainable fen produce, should be developed. Technological improvements and the pioneering work of the Broads Authority and its partners in the last 15 years mean that products such as compost and soil conditioner, bio-fuels and other green material could be commercially viable. These would provide an economic outlet for fen produce and pave the way for a new partnership to return the Broads to a vibrant economy based on a sustainably managed fen resource.

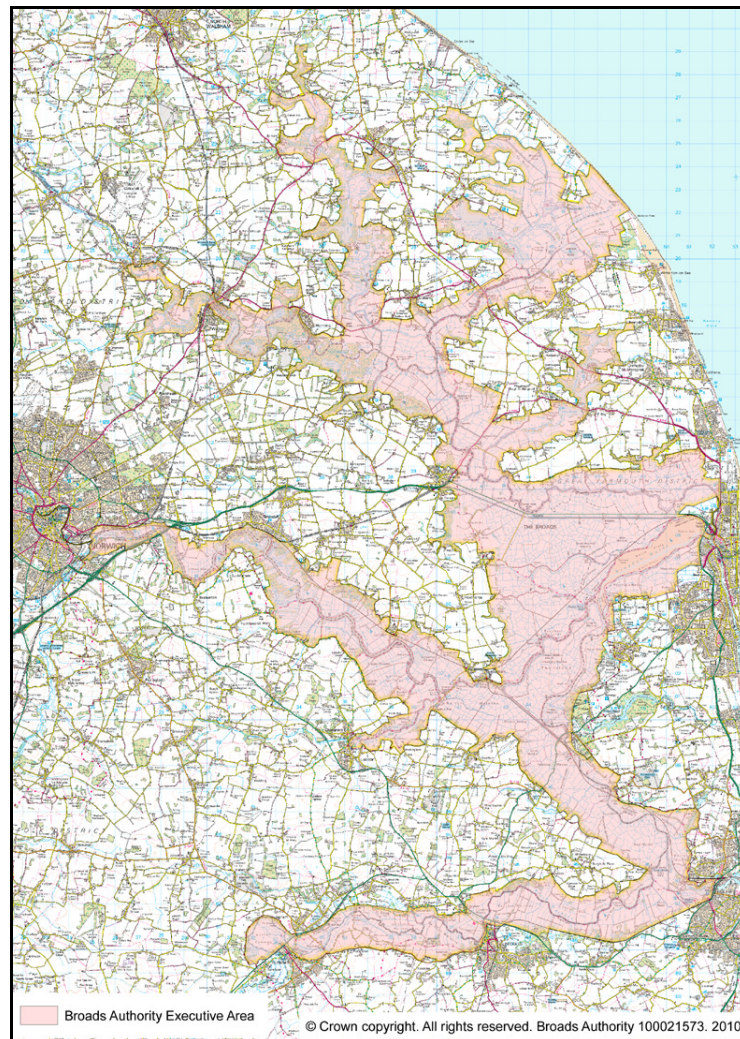
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I. INTRODUCTION

I.1 Study Area

All sampling was undertaken within the Broads Executive Area, as shown on Figure I.

Figure I: Broads Executive Area. Courtesy of the Broads Authority.



I.2 Previous Work And Project Origins

The first objective studies of Broadland vegetation were undertaken by Marietta Pallis (Pallis 1911) and Joyce Lambert and co-workers (Lambert 1946, 1947, 1948, 1951, 1965, Lambert and Jennings 1951, Jennings and Lambert 1951, Buttery and Lambert 1965, Buttery et al 1965) who were the first to rigorously describe the composition of different

fen types and their ecological relationships. They were also one of the first to articulate the processes which drove their genesis and their relationships to key environmental variables such as hydrology, water quality and management. Seminal though their work was, it was selective in the sites that were examined (particularly the Bure and Yare) and the methods used to describe the plant communities were very different to contemporary techniques.

There was then relatively little ecological work in Broadland fens until Bryan Wheeler undertook the first truly comprehensive and rigorous phytosociological study of British rich-fens (Wheeler 1980a-c)¹. Although the scheme of classification he derived was widely adopted and now forms the basis of the rich-fen sections of the NVC (Rodwell 1991b, 1995), the number of samples recorded from the Broads was relatively small and were carefully selected to represent particular fen vegetation types, rather than to provide comprehensive coverage and site descriptions (Wheeler 1980a). His Broadland fieldwork took place between 1972 and 1977. Wheeler and co-workers followed this with detailed and site specific ecological studies of particular fen types (Giller and Wheeler 1988) or particular eco-hydrological types such as the vegetation of turf ponds (Giller and Wheeler 1986), mainly in the Ant Valley (Wheeler 1978) and at Catfield Fen in particular.

The foregoing work was not, and never attempted to be, a survey of Broadland. The survey team associated with the NVC² similarly sampled the Broads vegetation but their aims were similar to Wheeler's and in any case their sampling of the fens was slight, utilising for the most part Wheeler's original data in their analysis.

The first true attempt at a comprehensive survey was undertaken by Parmenter (1995) in what was to become the first Fen Resource Survey. Parmenter's work was comprehensive in coverage, visiting most fen sites of significant size. However, density of sampling was not high (around 1676 samples in 2455ha of habitat, or one sample per 1.5 ha, which included fen scrub and carr and contact communities³). In addition, Parmenter derived her own vegetation communities in an entirely new classification. While her communities sometimes had analogues in the NVC, there was no precise correspondence (Parmenter 1995). The maps of vegetation type, derived from aerial photographs, were not always reliable and their presentation in Tolhurst (1997) aggregates communities into groups such as "swamps" or "eutrophic fen". As the communities were not understood intuitively by conservation workers, and the scheme as a whole was complex, the classification was not widely adopted in conservation practise. These, and other methodological differences⁴, mean that Parmenter's work is difficult to compare in its current form to this essentially NVC-led survey. Nevertheless, despite these limitations, this body of work does constitute the first comprehensive survey of Broadland which with some re-working of the data to re-align the communities with the NVC, and re-

¹ Rich-fen refers to wetland vegetation characterised by base-rich conditions. It is usually associated with pH which is circum-neutral and higher. Poor-fens are low pH, base-poor mires. Wheeler's initial work did not consider the latter.

² Although published in Rodwell (1992, 1995), the fieldwork took place between 1976 and 1979.

³ Contact communities are non-fen plant communities which are in close proximity to sampled habitats and which have some fen element (especially *Phragmites*) and therefore were included as possible fen samples.

⁴ Parmenter used a quadrat size of 2 x 2m for all vegetation types, in the mistaken belief this was the sample size used in the NVC (Parmenter 1995, vol 1, p.16 and p22).

mapping of the results, could provide a directly comparable data set from the early 1990's with which to compare the current survey.

There were a number of issues that relate to all of the previous work that compromise its use in site conservation. Sampling density was relatively low, meaning that as accounts of individual sites their value was limited. Locations of vegetation samples were based on six-figure grid references, and usually estimated. The previous work was mostly orientated toward specific ecological research requirements rather than providing information that supports the conservation and management of the fen resource. Their purpose was largely scientific rather than practical, with the exception of Parmenter's work which served both, although the issues described above limited its application.

1.3 Aims Of This Study

The current survey has the following aims:

- To provide an up to date and comprehensive survey of the Broadland herbaceous fen resource.
- To provide an overview of the relationship between fen types in the Broads.
- To summarise the conservation value (in botanical terms) of Broadland fens, including a description of what is unique and special about them.
- To provide a baseline understanding, as far as the supporting data allows, of the current condition of the fen resource.
- To provide a data base that supports both strategic planning for conservation and site-based restoration management planning.
- To provide a digital fen vegetation resource that can be layered and correlated with other ecological and environmental data sets.
- To identify fruitful areas of future research and development of the data set(s).

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2. METHODS

2.1 Field Survey

In 2005, a Pilot Study was undertaken (ELP 2005) which tested in the field the broad methods to be adopted. This was refined by discussion with the Broads Authority and Natural England teams, to derive the following field methodology.

2.1.1 Preliminary Work

Base maps on waterproof paper were prepared with Broads Authority compartment numbers shown. The most recent aerial photographs were also provided, printed to A4 and heat sealed. Both were gridded with the OS National Grid coordinates to aid navigation in the field using a 10-digit hand held GPS. The arials were helpful in identifying vegetation of different texture and colour for sampling, and allowed the surveyor to locate themselves within a few metres, even in the densest and tallest vegetation. It was an important health and safety tool in that it was almost impossible to get lost in the sometimes massive and featureless fen compartments, and avoided the surveyor walking into hidden hazards such as dykes and pools. The information was also essential to find (or re-find) crossing points and exits from fen compartments.

Each surveyor was assigned a set of sites at the start of the survey season. Sites known to be especially species-rich or liable to undergo management were prioritised for the peak of the flowering season, around July, and prior to any mowing management. Species-poor vegetation or those unlikely to support small herb floras were programmed for later in the year. Priorities were often disrupted by landowner issues and presence of Schedule 1 breeding birds, but in general the system worked well.

The surveyors were Jonny Stone, Kirsty Spencer and Mike Harding for all three summers of the main survey and for the Pilot Survey.

2.1.2 Vegetation Included in the Survey

The Broads Authority had previously mapped all of the compartments that contained significant areas of fen. All terrestrial herbaceous fen vegetation of the assigned compartments was included in the survey. Where surveyors noticed that adjacent areas were omitted but clearly were fen, these were included but no specific search to identify new fen was undertaken. No strict definition of fen was adopted; broadly all wetland vegetation other than woodland and wholly aquatic assemblages of open water was included. Communities transitional to dryland habitats, such as MG10 *Juncus effusus*-*Holcus lanatus* rush pasture, and a wide variety of wet grassland communities, were excluded although inevitably because of the gradual transitions to these communities some were sampled and have been described as "Contact Communities" in the results. A variety of saline habitats were included, as they contained or were dominated by fen plants and in particular *Phragmites*. Some have been classified as true saltmarsh communities but are retained in the fen accounts because of the reed component. A component of scrub would not exclude a stand (especially important here would be stands including *Myrica*

gale), but closed canopy scrub was not included. Every effort was made to sample awkward vegetation types such as hover and open water transition swamps, but health and safety considerations meant that the latter habitat in particular could not always be entered if water was deep. Hence single-species swamps characteristic of deeper broad margins may be under sampled in the data set.

Although the aim was to be comprehensive, some wetland communities such as the dune slacks at Winterton, swamp grass communities associated with foot drains in grazing marshes, the fen margins of dykes and the fragments of fen (especially fen meadow) within extensive areas of grazing marshes were not sampled. The effort required to sample this disparate resource was deemed too high for the returns

2.1.3 Selection of Sample Location

As far as possible the methods described in the National Vegetation Classification (Rodwell 1991b, 1995, 2000) were adopted. On species-rich sites, or where more detailed information was required as indicated by the Broads Authority, it was intended to map stands (defined as areas of visually uniform vegetation) and then to sample the stand. Stand definition was only straightforward on sites where traditional mowing regimes were still in place or where features such as dykes or fences marked stand boundaries. However, such situations are increasingly rare with extensive summer mowing long in decline or replaced with extensive grazing.

On very large, species-poor sites or fens that were grazed or which had not been managed for some time, it proved impossible to map stands directly. In particular, tall herb fen, especially stands with an upper tier of helophytes at chest height or above, could not be easily viewed to determine uniformity and stand boundaries. In many such sites, the vegetation communities appeared to merge one into another along seamless gradients where stand boundaries did not exist at all. Other than the practical impossibility of demarcating stand boundaries in the field in this kind of vegetation, to do so seemed to apply a degree of artificiality which was ecologically meaningless and obscured one of the key characteristics of the fen vegetation, that is, continual floristic variation.

Sometimes it was possible by examination of the aerial photograph to identify core areas of differing vegetation and start by sampling these to obtain a feel for the level of variation. Intervening areas could then be examined and sampling undertaken if such areas were deemed sufficiently distinct. On very large sites with very dense fen even this was not practical. Then, or where few or no core areas could be determined, the method was to walk the compartment, ensuring even coverage, sampling stands of vegetation that appeared to be distinctive and homogeneous over a sufficient area to sustain a sample.

While aerial photographs were invaluable in navigating the compartments, they do not always accurately distinguish vegetation communities. Areas that appeared to be an even green were often quite variable, the evenness being due to a masking tier of tall helophytes. Often, patches of apparently different tone or texture could simply reflect an increase in abundance of more prominent species, while the overall community was essentially the same. Many tall herb fens are patchy by nature, giving a false impression of a diversity of stands on the photograph. While aerials are a useful tool, then, they are not infallible.

2.1.4 Sampling Density

The aim of the sampling was to (a) cover the range of variation of fen vegetation and (b) sample at a sufficient density to provide a map of fen communities for the Broads. The survey had to both characterise the vegetation and provide an inventory of type, quantity and distribution. Because of the large area of fen, the latter purpose necessarily required intensive sampling.

For discrete stands in species-rich areas or for rare communities of any richness, more samples per unit area were taken, aiming for three to five samples per stand. In practise, sampling at the higher density was rare because of time constraints and also because the large numbers of samples being generated was becoming apparent. Stands which seem to have greater variation merited more intensive sampling than truly homogeneous stands.

For discrete stands in species-poor vegetation, two samples per stand were recorded. Enclaves of species-rich vegetation within tracts of poorer fen were sampled at higher density.

For vegetation without clear division into discrete stands (the most common circumstance), no sampling density could be predetermined. Sampling aimed to be sufficient to cover the range of variation observed.

Much of the time was taken in getting to and around the site. Taking extra samples is proportionately less time consuming, so if there was doubt and time allowed, there was a presumption on taking more samples.

2.1.5 Recording in Each Stand/Sample

Sample size and placement was consistent with the National Vegetation Classification. We followed the recommendations of Rodwell (1991b, 1995) with mires and fen meadows being sampled with 2 x 2m, 4 x 4m or exceptionally 10 x 10m quadrats and tall herb fens with 4 x 4m or 10 x 10m quadrats. The larger sizes were employed for species-poor vegetation. All species of higher plant, liverwort and moss were recorded and rated for abundance on the DOMIN scale.

Information on vegetation structure was recorded for each sample, including plant litter cover, bryophyte cover, open water cover, bare ground cover, sward height and total vegetation cover.

2.1.6 Field Mapping and Analysis

Location of samples was indicated on field maps as far as possible. Sample locations were recorded with a 10-digit hand-held GPS. Although it was the intention to produce maps of stands this proved impossible for reasons described above. Indeed, a map of artificial stand boundaries imposed on vegetation which is naturally gradational is ecologically inappropriate, and the attempt was largely abandoned in later years of the survey. The scatter of vegetation samples coded to community provides a vegetation map itself (especially at the density of sampling that was achieved during this survey) and one that better accommodates the vegetation gradients. The aerial photograph, for which there is

comprehensive coverage for all of the Broads, overlain with sample locations, provides the best mapping of all and this is the presentation that will be achieved in the project GIS.

Data were then entered into the data base. No further analysis was undertaken until the end of the final year. All original field maps, data sheets and aerial photographs have been retained.

2.2 Data Analysis

2.2.1 Data Recorded

A total of 7038 samples were recorded in 1750 ha of fen, a density of one sample per 0.249ha, or four samples per hectare. The samples were assembled in the main database, an Excel spreadsheet. The data set included 451 taxa.

2.2.2 Initial Preparation and Analysis

The very species-poor samples (five species or less) were split off from the data set prior to computer analysis, as they were thought likely to distort the main classification results. These samples were hand sorted into communities, based initially on dominant species. This worked well, as most of these stands were strongly dominated by one (sometimes two) tall helophytes, sometimes with a lower layer of bulky sedges, plus a few sparse and infrequent herbs or bryophytes.

2.2.3 TWINSpan Analysis

The initial approach with the remaining data set was to classify all of the samples through a TWINSpan analysis. This separated some clearly very different vegetation types, such as the saline vegetation and the contact communities which then went on for further analysis by MATCH and hand sorting.

TWINSpan did not separate some of the core fen communities such as S24 very well, leaving some end groups with a thousand or more samples with little clear differentiation. Further subdivision of these bulk groups were associated with very low Eigen values suggesting low confidence in the split. Although the TWINSpan end groups were an invaluable first sift of the vegetation, further analysis of the mire and swamp vegetation was required using Match and by hand sorting. Combining TWINSpan and hand sorting is a standard technique in vegetation analysis (adopted for instance by the NVC team, see Rodwell 1991b) as the computer programme is automated and provides end groups which need to be ecologically interpreted. However, because of the large body of relatively undifferentiated samples in many end groups, this hand sorting stage was more all-embracing than in many classification routines.

The purpose of the work was not a root and branch reclassification of fen vegetation, and it was not within the remit to produce a new classification as did for instance Parmenter (1990). It was clear that the project partners wished, as far as possible, to keep the classification within the broad remit of the NVC, although it was hoped that entirely novel communities would emerge and unsatisfactory NVC communities would be identified. Hence in examining end groups and in our hand sorting operations, the NVC provided the overall guide to assembling the plant communities.

In many ways, then, this is not a pure phytosociological approach. The process was essentially a TWINSpan-assisted NVC survey, and in this sense it has worked very well, providing a good classification of a large body of samples suitable for mapping and interpretation. It is an approach that had been used successfully in other broad scale surveys of large habitat blocks where the standard five samples per stand routine was not possible to pursue – the 2200ha of species-rich grassland of the Stanta battle training area (ELP 2006) and the enormous area of vegetated shingle at Dungeness (ELP 2008) are examples.

The greatest difficulty in this approach was the sheer volume of data. Viewing spreadsheets of perhaps 1000 sample-columns and 400 species-rows is extremely testing. Many days of examining these data sets was required to identify patterns, and in this process an initial assessment of each sample using MATCH undertaken by Bryan Wheeler proved an invaluable starting point.

2.2.4 Resolving Communities

Some communities, such as M22 *Juncus subnodulosus*-*Cirsium palustre* vegetation resolved relatively easily. Others such as M24, M13 and M9, which had far fewer samples, proved more difficult. The boundaries between these communities are poorly defined in the NVC as acknowledged by Rodwell (1991b), with a great deal of overlap. Perhaps one of the most difficult of all to resolve was S24 *Peucedanum palustre*-*Phragmites australis* fen, the classic Broadland tall herb fen. This vegetation unit included the biggest data sets whose compendious TWINSpan end groups were least satisfactory.

Further analysis was performed on the most difficult communities (M9, M13, M24 and S24), by assessing the number of “character species”⁵ as defined by Wheeler, Shaw and Tanner (2009). Samples were moved to the community with the most character species, as long as the overall floristics justified such a move. This routine greatly improved the definition of the communities, and most were satisfactorily resolved.

In terms of the swamps and tall herb fens, the bulk of the vegetation, Rodwell (1995) notes that any classification of this material can be driven either by the dominant species which forms an upper tier to the vegetation or by the group of associated species in the under-storey. He provides a list of twenty four dominant species. They are either tall grasses, such as *Phragmites*, bulky sedges such as *Carex paniculata*, or lower-growing species typical of water margins, such as *Eleocharis palustris*. Rodwell identifies eight groups of associated species, half of which are species-rich groups, and the other half species-poor or fragmentary groups.

When the 24 dominant species are cross-tabulated against the eight groups of associates, the overall pattern of this chapter of the NVC emerges. Vegetation which is dominated by a single species, and is associated with one of the four species-poor assemblages, it is largely classified according to the dominant species. The community takes the name of that species. If there is sufficient variation in the under-storey associates, sub-communities

⁵ Character species are plants which were strongly preferential to these communities and should be present for the sample to be assigned to this type

can be defined on the basis of one of the four species-poor groups of associates. The resulting communities are mostly mono-dominant swamps.

Where the suite of associates is much richer, the community tends to be defined by these groups rather than the dominant species. The latter is often used to define the sub-community, although this convention does not hold for the more complex S24 community. There are four NVC communities defined by species-rich assemblages of associates, the tall herb fens of S24, S25, S26 and S27.

Rodwell's approach combines the simplicity of defining mono-dominant swamps in the simplest fens, with utilisation of the full floristic variation available in the complex and species-rich vegetation types. Any community which did not appear to fit the reference NVC community tables was compared to Rodwell's cross-tabulation to identify whether or not it was perhaps just a poor fit, or an intermediate. If not, it was proposed as a new community.

2.2.5 Reasons for poorness of fit with the reference NVC community

Although the overall fit with the reference NVC communities is good for most of the final end-groups in this survey the *Results* section below notes that some have a poor fit. Vegetation types in the current survey often had fewer preferentials diagnostic of the NVC type and a reduced suite of frequent species and are often less rich than the published communities. There are a number of factors which may contribute to these observations.

The first is that we were often matching very large sample sets against NVC communities that were defined by Rodwell (1991b, 1995, 2000) using small numbers of samples. Inevitably, the current much larger sets of samples include a much greater spread of floristic variation. A purer phytosociological treatment might consider many of the samples as noise or transitional to an adjacent stand type. The 20 or so samples that best reflected the NVC type ⁶ could have been plucked out from the large bodies of samples in the current data, producing a mirror-image community profile, but this would have served no purpose for our survey with its need to classify and allocate all of the samples.

The lack of fit of some of the communities therefore reflects the fact that in the field, fen vegetation is much more variable, and the nature of that variation is more continuous, than the discrete nodes which Rodwell (1991b, 1995, 2000) and Wheeler (1980a-c) describe in their pure phytosociological analyses. Herein lies a fundamental difference between their work and the current survey. Rodwell and Wheeler were erecting a framework within which to interpret all fen vegetation, identifying a series of reference points that other workers could use to place their own samples. The current survey was a field description of the whole fen resource, which out of necessity needed to include samples which were recorded between the fen community reference points. Hence, the boundaries drawn around some of the communities described here have a much wider compass than the more tightly circumscribed reference communities. In that sense, the communities in this survey more accurately describe the vegetation which we encountered in the field, but at the expense of "fit" with reference communities.

⁶ Discarding samples that are simply "noise" or intermediates, is a common practise in pure phytosociological studies but was not an option available in this study.

A second reason for the lack of match is that the NVC is based on field data recorded 30-40 years ago. Many of these communities are likely to have undergone change, through changing management practises, changes in hydrology and water chemistry, and autogenic changes in what are dynamic vegetation types. It is possible that the differences between our and Rodwell's communities in part reflect broader changes in the habitat conditions over the intervening decades. There is very little hard evidence to underpin this proposition, but there is a very large body of circumstantial evidence discussed below. Broader environmental change may produce poor fit, the development of previous unidentified vegetation types or changes in quality factors such as species-richness.

Thirdly, it appears that the samples used to build the NVC communities were often of a different size to those indicated by Rodwell himself. Bryan Wheeler (in litt., 2010) indicated that all his samples, which formed the bulk of the fen NVC, were recorded as 10 x 10m, including fen meadows and mires, and regardless of species-richness. This is a little over six times the 4 x 4 size used in this survey for most fens and 25 times the size of quadrats used for fen meadows. Inevitably, Wheeler's samples would have recorded many more species, and community profiles compiled from them would be more species-rich and would have more constants, a greater suite of other species at medium frequency and better defined preferentials. Rodwell (in litt 2010) has confirmed that much of the tall herb fen section was compiled from Wheeler's data, but less so mires and fen meadows which had a more mixed source of data. It is therefore not possible to quantify to what degree the NVC has been affected by samples of mixed or different sizes, and to what degree this accounts for differences between the communities derived here and the reference types. This issue will also affect the results of Parmenter (1995) who used a 2 x 2m sample.

Finally, our data have been produced by very intensive sampling of a relatively local area, while the NVC was derived from selected sampling across the whole of the UK. Our data is therefore likely to be strongly skewed by local phyto-geographical, environmental and management factors. This is of course what makes the Broads vegetation distinctive and is an important part of its character. The significance of these factors is least on NVC communities such as S24 which are almost entirely centred on the Broads, even in Rodwell (1995). The regional effect is greater on communities that have a national distribution, such as the mires, and is particularly acute with communities such as M23 and M25 which are described by Rodwell (1991b) as west and north of Britain communities and absent from East Anglia.

Most of these issues are not problems *per se*. Understanding that the vegetation described here is different from the published reference communities is an important part of interpreting the results of the survey and understanding the nature of Broadland fen communities. However, confusion is provided by the quadrat size issue, as we cannot be quite sure that the differences observed are entirely due to environmental factors. Unfortunately, the significance of this cannot now be quantified.

2.2.6 Defining New Communities

In the *Results* section, entirely new communities, new sub-communities of established NVC communities, and new variants of established NVC sub-communities are variously

proposed. The criteria for suggesting these new units are the same whatever their level. The primary criteria are:

- That they should have clear floristic identity which is demonstrably separate from the published NVC units. In the case of swamps and tall herb fens, the newly proposed unit was compared to Rodwell's (1995) cross-tabulation of dominants and associates to ensure the vegetation type was clearly different.
- They should not be an intermediate type, that is, a simple blend of two well separated communities. They should have a community profile which is significantly different from simply shuffling together the floras of two "parent" reference communities.
- They should relate to a significant set of samples (usually 15 or more), which is equal to or larger than that of many units of the NVC.
- They should not be drawn from one site which may reflect an unusual and site specific set of ecological circumstances. In other words the unit is replicated and represents a community with wide applicability, even if the community is rare.

A secondary criterion which supports the above was:

- The community should be recognisable in the field, at least, as much as any of the NVC units are.

Of all of these criteria, that relating to avoiding intermediates is the most difficult to apply objectively. Many NVC communities, especially those later than pioneer swamps in the hydrosere succession, can be regarded as intermediates, having other units either side of them in any schematic arrangement of NVC types along an environmental gradient (see Rodwell 1991b, 1992 and 1995 for examples). Whether a community represents an important step on the gradient which should be recognised as a new reference community, or whether it is simply an intermediate, can at times be a matter of judgement.

It would be helpful if there were a peer-reviewed process for accepting new communities into the nationally agreed series. Until this is the case, vegetation types proposed here should be considered provisional.

3 RESULTS

3.1 Introduction

Table I provides a summary of the final vegetation types derived in this survey. A detailed description of the communities, a range of floristic metrics and an assessment of the goodness of fit to reference NVC communities, is provided in Appendix I.

Table I: Summary of Plant Communities. Communities prefixed BS X (Broads Survey) are new communities proposed in this report, those prefixed BS(x) are new sub-communities. New variants are not given prefixes. Number of samples/area given for a community is the sum of that for all of the sub-communities⁷.

Code	Title	No. samples	Area
M9	<i>Carex rostrata</i> – <i>Calliergonella cuspidata/giganteum</i> mire	1	0.2
M13	<i>Schoenus nigricans</i> - <i>Juncus subnodulosus</i> mire,	22	5.5
	(c) <i>Caltha palustris</i> - <i>Galium uliginosum</i> sub-community.	22	5.5
M22	<i>Juncus subnodulosus</i> - <i>Cirsium palustre</i> fen meadow,	406	101.1
	(a) Typical sub-community Typical variant	88	21.9
	(a) Typical sub-community, <i>Carex nigra</i> variant	11	2.7
	(a) Typical sub-community, <i>Juncus effusus</i> variant	12	3.0
	(a) Typical sub-community, <i>Juncus acutiflorus</i> variant	5	1.2
	(b) <i>Briza media</i> - <i>Trifolium</i> spp sub-community	188	46.8
	(c) <i>Carex elata</i> sub-community	15	3.7
	(d) <i>Iris pseudacorus</i> sub-community	87	21.7
M23	<i>Juncus acutiflorus</i> - <i>Galium palustre</i> rush pasture,	58	14.4
	(a) <i>Juncus acutiflorus</i> sub-community	14	3.5
	(b) <i>Juncus effusus</i> sub-community	44	11.0
M24	<i>Molinia caerulea</i> - <i>Cirsium dissectum</i> mire,	47	11.7
	(a) <i>Eupatorium cannabinum</i> sub-community.	14	3.5
	(b) Typical sub-community.	30	7.5
	(c) <i>Juncus acutiflorus</i> - <i>Erica tetralix</i> sub-community.	3	0.7
M25	<i>Molinia caerulea</i> - <i>Potentilla erecta</i> mire,	19	4.7

⁷ Area is calculated by multiplying the number of samples by the mean area per sample (0.249 ha) for the whole survey.

	(b) <i>Anthoxanthum odoratum</i> sub-community	19	4.7
S1	<i>Carex elata</i> sedge-swamp	3	0.7
S2	<i>Cladium mariscus</i> swamp,	144	35.9
	(a) <i>Cladium mariscus</i> sub-community	144	35.9
Intermediate :	S2b <i>Cladium mariscus</i> sedge-swamp, <i>Menyanthes trifoliata</i> sub-community and S25c <i>Phragmites australis</i>-<i>Eupatorium cannabinum</i> fen, <i>Cladium mariscus</i> sub-community	209	52.0
S4	<i>Phragmites australis</i> swamp,	1336	332.7
	(a) Typical sub-community, <i>Cladium mariscus</i> variant	51	12.7
	(a) Typical sub-community, <i>Solanum dulcamara</i> variant	373	92.9
	(a) Typical sub-community, <i>Lemna</i> spp variant	95	23.7
	(a) Typical sub-community, <i>Agrostis stolonifera</i> variant	116	28.9
	(b) <i>Galium palustre</i> sub-community, Typical variant	319	79.4
	(b) <i>Galium palustre</i> sub-community, <i>Agrostis stolonifera</i> variant	142	35.4
	(d) <i>Atriplex prostrata</i> sub-community, no variant assigned	92	22.9
	(d) <i>Atriplex prostrata</i> sub-community, ii <i>Puccinellia maritima</i> variant	26	6.5
	(d) <i>Atriplex prostrata</i> sub-community, iii <i>Agrostis stolonifera</i> variant	28	7.0
	BS(e) <i>Utricularia vulgaris</i> - <i>Potamogeton coloratus</i> - <i>Hydrocharis morsus-ranae</i> sub-community	17	4.2
	BS(f) <i>Lemna minor</i> sub-community	28	7.0
	BS(g) <i>Solanum dulcamara</i> - <i>Calystegia sepium</i> sub-community	14	3.5
	BS(h) <i>Carex acutiformis</i> sub-community	17	4.2
	BS(i) <i>Calamagrostis canescens</i> sub-community	18	4.5
Intermediate:	S4d <i>Phragmites australis</i> swamp, <i>Atriplex prostrata</i> sub-community SM24 <i>Elytrigia atherica</i> saltmarsh community	20	5.0
Intermediate:	S4b <i>Phragmites australis</i> swamp, <i>Galium palustre</i> sub-community S13 <i>Typha angustifolia</i> swamp	26	6.5
BS1	<i>Phragmites australis</i>-<i>Carex riparia</i> swamp	61	15.2
S5	<i>Glyceria maxima</i> swamp , no sub-community	24	6.0
S5	<i>Glyceria maxima</i> swamp,	26	6.5
	(a) <i>Glyceria maxima</i> sub-community	24	6.0
	(b) <i>Alisma plantago-aquatica</i> - <i>Sparganium erectum</i> sub-community	2	0.5
Indeterminate	<i>Glyceria maxima</i> fen	8	2.0

S6(1)	<i>Carex riparia</i> swamp	17	4.2
S6(2)	<i>Carex riparia</i> swamp	11	2.7
S7	<i>Carex acutiformis</i> swamp	25	6.2
Intermediate:	S6 <i>Carex riparia</i> swamp S7 <i>Carex acutiformis</i> swamp	47	11.7
BS2	<i>Carex acutiformis</i>-<i>Filipendula ulmaria</i> fen	84	20.9
S8	<i>Schoenoplectus lacustris</i> swamp	15	3.7
S9	<i>Carex rostrata</i> swamp	2	0.5
S12	<i>Typha latifolia</i> swamp,	34	8.5
	(b) <i>Mentha aquatica</i> sub-community	28	7.0
	(c) <i>Alisma plantago-aquatica</i> sub-community	6	1.5
S13	<i>Typha angustifolia</i> swamp	9	2.2
S14	<i>Sparganium erectum</i> swamp,	32	8.0
	(a) <i>Sparganium erectum</i> sub-community	5	1.2
	(b) <i>Alisma plantago-aquatica</i> sub-community	1	0.2
	(c) <i>Mentha aquatica</i> sub-community	26	6.5
S17	<i>Carex pseudocyperus</i> swamp	1	0.2
S19	<i>Eleocharis palustris</i> swamp	3	0.7
S20	<i>Schoenoplectus tabernaemontani</i>	11	2.7
	(b) <i>Agrostis stolonifera</i> sub-community	11	2.7
S21	<i>Bolboschoenus maritimus</i> swamp	54	13.4
	(a) <i>Bolboschoenus maritimus</i> sub-community	3	0.7
	(b) <i>Atriplex prostrata</i> sub-community	11	2.7
	(c) <i>Agrostis stolonifera</i> sub-community	40	10.0
S22	<i>Glyceria fluitans</i> swamp,	1	0.2
	(a) <i>Glyceria fluitans</i> sub-community	1	0.2
S24	<i>Phragmites australis</i>-<i>Peucedanum palustre</i> reed fen,	1229	306
	(a) <i>Carex paniculata</i> sub-community	148	36.9
	(b) <i>Glyceria maxima</i> sub-community	30	7.5
	Intermediate : (b) <i>Glyceria maxima</i> sub-community and (c) <i>Symphytum officinale</i> sub-community	88	21.9
	(d) Typical sub-community	298	74.2

	(e) <i>Cicuta virosa</i> sub-community	159	39.6
	(f) <i>Schoenus nigricans</i> sub-community	175	43.6
	(g) <i>Myrica gale</i> sub-community	331	82.4
BS3	<i>Phragmites australis</i> - <i>Calamagrostis canescens</i> fen	154	38.3
BS4	<i>Calamagrostis canescens</i> fen	8	2.0
Intermediate :	S24 <i>Phragmites australis</i>-<i>Peucedanum palustre</i> fen, S25 <i>Phragmites australis</i>-<i>Eupatorium cannabinum</i> fen	1025	255.2
	<i>Eleocharis uniglumis</i> fen	3	0.7
	<i>Myrica gale</i> fen	3	0.7
S25	<i>Phragmites australis</i>-<i>Eupatorium cannabinum</i> fen,	170	42.3
	(a) <i>Phragmites australis</i> sub-community	41	10.2
	(c) <i>Cladium mariscus</i> sub-community	129	32.1
S27	<i>Potentilla palustris</i>-<i>Carex rostrata</i> tall herb fen	79	19.7
	a) <i>Carex rostrata</i> - <i>Equisetum fluviatile</i> sub-community	7	1.7
	b) <i>Lysimachia vulgaris</i> sub-community.	72	17.9
Intermediate:	S27b <i>Potentilla palustris</i>-<i>Carex rostrata</i> tall herb fen, <i>Lysimachia vulgaris</i> sub-community M5 <i>Carex rostrata</i>-<i>Sphagnum squarrosum</i> mire.	11	2.7
BS5	<i>Dryopteris cristata</i>-<i>Sphagnum species</i> fen	57	14.2
S26	<i>Phragmites australis</i>-<i>Urtica dioica</i> fen,	786	195.7
	(a) <i>Filipendula ulmaria</i> sub-community.	119	29.6
	(b) <i>Arrhenatherum elatius</i> sub-community.	96	23.9
	(b) <i>Arrhenatherum elatius</i> sub-community, Saline Variant	21	5.2
	(d) <i>Epilobium hirsutum</i> sub-community.	281	70.0
	BS(e) <i>Calamagrostis canescens</i> sub-community	134	33.4
	BS(f) <i>Carex species</i> fen	15	3.7
	BS(g) Species-poor sub-community	120	29.9
Intermediate:	S26(a) <i>Phragmites australis</i>-<i>Urtica dioica</i> fen, <i>Filipendula ulmaria</i> sub-community and S5(a) <i>Glyceria maxima</i> swamp, <i>Glyceria maxima</i> sub-community	20	5.0
OV26	<i>Epilobium hirsutum</i> community,	149	37.1
	(b) <i>Phragmites australis</i> - <i>Iris pseudacorus</i> sub-community	139	34.6
	(c) <i>Filipendula ulmaria</i> - <i>Angelica sylvestris</i> sub-community	8	2.0

	(d) <i>Arrhenatherum elatius</i> - <i>Heracleum sphondylium</i> sub-community	2	0.5
S28	<i>Phalaris arundinacea</i> fen,	25	6.2
	(a) <i>Phalaris arundinacea</i> sub-community	3	0.7
	(b) <i>Epilobium hirsutum</i> - <i>Urtica dioica</i> sub-community	22	5.5
SM13	<i>Puccinellia maritima</i> saltmarsh,	2	0.5
	(d) <i>Plantago maritima</i> - <i>Armeria maritima</i> sub-community	2	0.5
SM16	<i>Festuca rubra</i> saltmarsh,	72	17.9
	(a) <i>Puccinellia maritima</i> sub-community	26	6.5
	(b) <i>Juncus gerardii</i> sub-community	29	7.2
	(c) <i>Festuca rubra</i> - <i>Glaux maritima</i> sub-community, (i) <i>Agrostis stolonifera</i> variant	17	4.2
SM20	<i>Eleocharis uniglumis</i> saltmarsh	2	0.5
SM23	<i>Spergularia marina</i>-<i>Puccinellia distans</i> saltmarsh	3	0.7
SM24	<i>Elytrigia atherica</i> saltmarsh	4	1.0

The following essentially non-fen communities were also recorded incidentally:

- MG13 *Agrostis stolonifera*-*Alopecurus geniculatus* grassland
- MG10 *Holcus lanatus*-*Juncus effusus* rush pasture,
- (a) Typical sub-community
- (b) *Juncus inflexus* sub-community
- OV27 *Chamerion angustifolium* community
- OV30 *Bidens tripartita*-*Polygonum amphibium* community

Most of the new communities are associated with S4 species-poor reedbeds and eutrophic fens, particularly S26. Both areas of fens and swamps within the NVC could usefully be comprehensively re-examined as the evidence of this survey suggests Rodwell (1995) does not adequately describe the true range of variation.

3.2 Presentation of Data and Maps

The size of the data set and the number and size of the maps means that it could not all be presented in the body of this report. Much of the data is therefore included on the disk attached to the report. The available data and analyses are:

- **The Plant Communities.** An Excel spreadsheet which contains all of the samples recorded in the survey, assembled into plant communities, along with their constancy profiles. Intermediates appear on maps of both parent communities.
- **The Master Data Table.** An Excel spreadsheet which provides all of the raw sample data, unsorted. Each sample has a unique reference. The samples are presented in a single matrix, where the columns are the samples and the rows

the species. It also contains all of the associated data recorded with each quadrat, for example, % litter cover, total herb cover etc.

- Each of the samples has a value calculated for Ellenberg's indicator values (for salinity, fertility, reaction (i.e. pH), light and moisture. The Ellenberg values (Hill et al 1999) are a numerical rating given to each plant species according to its place on the spectrum of each determinant. So, for salinity, saltmarsh species have a high salinity value, freshwater marsh species a low one. A total score can be calculated for each sample, indicating how brackish the conditions are where the sample was recorded. Mapping these scores then gives an indication of the distribution of brackish fen types. Such maps allow a geographical appreciation of distribution of habitat factors, always understanding these values are inferred from the vegetation and not measured directly. Light levels are perhaps least useful as it largely reflects stature of the vegetation, itself moderated by management.

Similarly, the spreadsheet calculates for each sample the Rarity Weighted Principle Fen Species Score (RWPFSS), as conceived by Wheeler (1988). This is an index of the botanical value of each fen sample. A Principle Fen Species is one which is closely associated with fen vegetation. Although not all are restricted to fens (many are), all are largely dependent on fens for their conservation. It is a similar concept to ancient woodland indicators. A score is derived for each sample based on the number of principle fen species it includes. A weighting is applied to rare species, this weighting being derived by Wheeler from the frequency of occurrence of each species recorded in his fen data set. The higher the score, the more important the sample is for botanical conservation. Note however that the RWPFSS is based on species-richness and rarity, which are not the only way to evaluate a conservation feature. These data should therefore be interpreted cautiously.

- **Plant Community Summary Data.** A third Excel spreadsheet provides a summary for each vegetation unit including the mean for each of the stand metrics, the Ellenberg values and the RWPFSS, allowing comparison between vegetation types.
- **GPS Data.** A fourth Excel spreadsheet provides the 10-digit GPS reference for every sample, along with its unique reference number.
- **The NVC Maps,** showing all of the samples together, coded for their NVC community. These are as large format JPEGs. They allow the viewer to consider how the communities are juxtaposed and how they relate to each other and potential environmental gradients. Extracts from these maps are used in the text.
- **Community Maps,** showing the distribution of specific communities in isolation. It is difficult to search for specific communities of interest on the NVC maps, especially the less frequent ones, so community maps allow easier searching and a better appreciation of the distribution of individual vegetation types. Only the major NVC types have been separately mapped.

- **Sample Number Maps.** The unique sample number is shown on the base maps. For casework and conservation management, these maps allow identification of all samples so that the original data can be extracted from the main spreadsheets and interrogated as required.
- **Ellenberg Maps.** Samples are mapped and colour coded according to their Ellenberg value. The colour codes show classes of Ellenberg value.
- **RWPFSS Maps.** Samples are mapped and colour coded according to their RWPFSS value. The colour codes show classes of RWPFSS value. These provide an indication of the distribution of the richest fen types.

All of this material is referred to in the following text to varying degrees. Further analysis exploring relationships between the data sets could be rich territory, and hence the raw data is made available for those who would wish to pursue these research avenues. Hence the data set, and this report, should be considered a starting point, not an end point.

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4 OVERVIEW OF THE FEN COMMUNITIES OF BROADLAND

4.1 Introduction

Table 1 in the *Results* section indicates a large number of NVC communities, sub-communities and variants that were recorded in the survey. In terms of the NVC chapters, they were mostly Mires, Swamps and Tall Herb Fens, and Saltmarsh vegetation. There were some Mesotrophic Grassland communities but these were contact communities on dryer ground sampled because they superficially resembled fen in the field. OV26, placed in the Open Vegetation chapter of the NVC is essentially a fen community and will be discussed in the Tall Herb Fen section below.

The following account is intended to provide an overview of the fen communities found. Detailed ecological accounts of all of the NVC communities can be found in Rodwell (1991b, 1995, 2000) and other authors have provided much additional information about certain communities or their Broadland context (see for example George 1992, Giller and Wheeler 1986, 1988, Wheeler 1978, Wheeler Shaw and Tanner 2009, Wheeler 1980a-c). Classic accounts of Broadland fens are provided by the work of Pallis and Lambert and their co-workers – see references for the main studies. Parmenter's (1995) survey is published in a series of BA reports. The main aim of the following account, other than to amplify the results of the survey, is to suggest what has been learned in addition to these accounts, what may have changed in Broadland since these accounts were made, and to flag what requires further research.

4.2 Mires and Fen Meadows

Most of the mires (which include fen meadow communities in Rodwell's (1991b) scheme) are base-rich, calcareous and with a pH at or above neutral. Poor fen and acid mire communities are generally not characteristic of Broadland and were rarely sampled. Most poor fen vegetation recorded in this survey is discussed in the Swamps and Tall Herb fen sections as they are either sub-communities of, or are transitional with, these vegetation types. There are some vegetation types which appear to hover around neutral to mildly acid conditions – M23 *Juncus effusus/acutiflorus-Galium palustre* rush pasture and M25 *Molinia caerulea-Potentilla erecta* mire – but these communities are more usually recorded in the west and north of Britain. The samples recorded in the Broads do not match well the reference communities, partly because of their geographical dislocation and partly because the substrates they occupy are probably a little too eutrophic and base rich compared to those where the reference types were sampled. Nevertheless, they describe a significant kind of variation in a flora which is otherwise overwhelmingly dominated by base rich mires.

Mires and fen meadows are almost always a secondary vegetation type, derived from the tall herb fens, described later, through annual cutting for marsh hay or by grazing. While there is an argument for considering M13 *Schoenus-Juncus* mire a primary community arising without management (Rodwell 1991b), this is usually in the context of its typical locations at spring heads or very strong groundwater seepages, where very low nutrient

conditions keep competition to a minimum. In the Broads floodplains, such conditions are rare or absent. The community would need to be managed to prevent overwhelming dominance of reed or *Cladium*.

Fen meadows recorded in this survey were mostly restricted to the heads and margins of the main river valleys, or were located in the small sites typical of the narrower tributary valleys. They were rather rare in the centre of the floodplains and even rarer along river margins. M22 and M24 could exist in floodplain areas if the marshes are mown sufficiently frequently, and perhaps were more commonplace in these locations in former times. However, the valley margins are more convenient for management, and are often a little drier which would have facilitated grazing. Much of the valley side to floodplain transition has been truncated by agricultural improvement, to the detriment of mire and fen meadows.

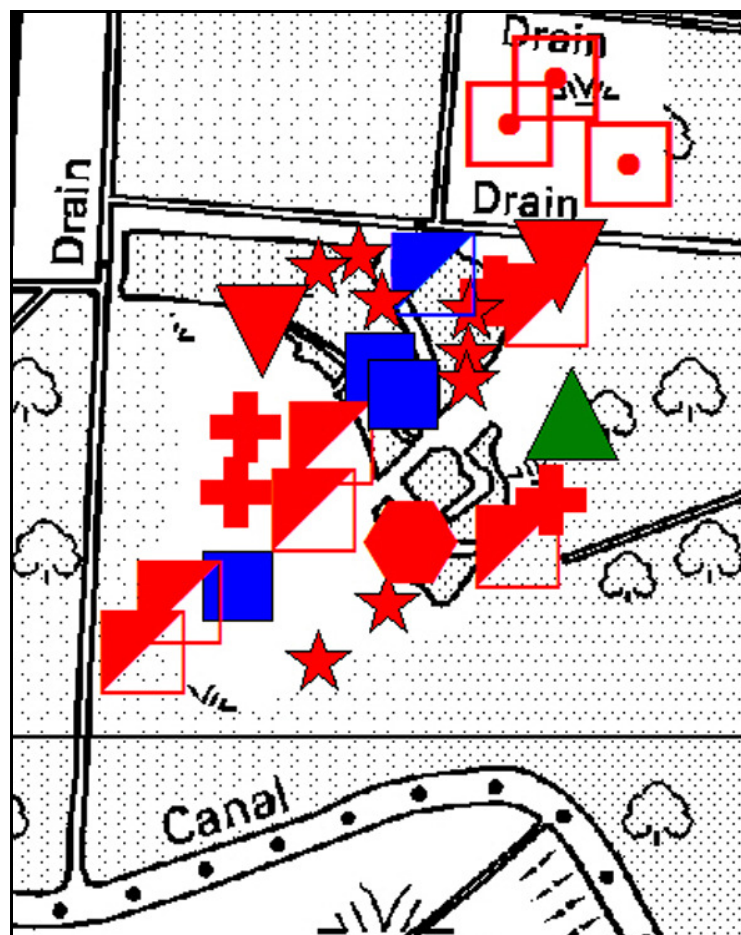
4.2.1 True mires: M9 and M13

Only one sample in this survey has been referred to M9 *Carex rostrata-Calliergon cuspidata/giganteum* mire, and this was not an especially good fit. In the Broads, this would be a community of shallow peat cuttings supplied with low nutrient and calcareous water. It has been recorded mostly in the Ant valley and rarely also in the Bure, when it was first recognised as *Peucedano-Phragmitetum caricetosum* by BD Wheeler (1980a) and subsequently placed in M9 by Rodwell (1991b). It was disappointing and perhaps surprising that more stands were not recorded. The reasons for this are not at clear but are discussed more fully under S24 where *P.-P. caricetosum* is further considered.

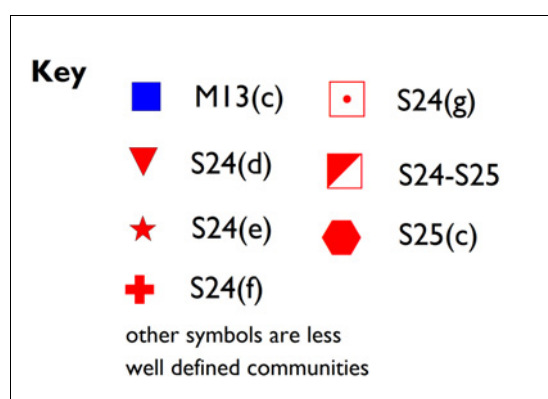
A second rare community of great conservation value is M13 *Schoenus nigricans-Juncus subnodulosus* mire. This community, most usually associated with groundwater seepage in valley fens, recorded only 22 samples in the survey, which were assigned to the *Caltha palustris-Galium uliginosum* sub-community, associated with wet conditions. A further 7 samples has some affinity to M13, but could not be assigned to a sub-community. With a mean species number of 34.2 per sample, this was the richest community of all and recorded a wide range of uncommon fen plants. The number of sites it was recorded from was also low, and included the classic Broadland site at Smallburgh Fen, but also Ducan's Marsh and Broad Fen, Dilham. The first two are valley fens, typical locations for M13, but other samples were located on the floodplain, usually in former peat cuttings.

The relationship of the floodplain examples of M13 with tall herb fens of the S24 *Phragmites-Peucedanum* community, and Wheeler's "lost" *Peucedano-Phragmitetum caricetosum* is unclear. Field experience suggests these M13 samples are quite close in structure and composition to very rich examples of S24 and further phytosociological investigation may suggest the samples assigned to M13 here have a close relationship with Wheeler's *P.-P. caricetosum*. At Broad Fen, for instance, (see Figure 2) stands of M13 were mostly surrounded by a mosaic of the *Schoenus nigricans* and *Cicuta virosa* sub-communities of S24. The M13 vegetation recorded in floodplain shallow cuttings share the habitats and hydrochemistry of *Peucedano-Phragmitetum caricetosum*, and may share at least some common origins.

Figure 2: The South Part of Broad Fen, Dilham, in the River Ant Catchment.



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In any case, shallow peat diggings seem essential for the continued survival of this and many of the highest quality wet fen types in Broadland.

4.2.2 Calcareous Fen Meadows

M24 *Molinia caerulea*-*Cirsium dissectum* fen meadow is associated with low nutrient conditions, and where fertility is particularly low and water tables high, it can merge into dryer forms of M13. It was an uncommon community in the Broads, with only 47 samples recorded during this survey. Three samples were a rather poor fit to the *Juncus acutiflorus*-*Erica tetralix* sub-community, the vegetation type which is transitional to poor fen and wet heath. The other two sub-communities are strongly associated with calcareous conditions. The most common of these, the *Eupatorium cannabinum* sub-community, has a significant complement of tall herb fen species from which it was derived, especially *Phragmites*. It is most typically recorded on the margins of floodplain fens (Rodwell 1991b). The Typical sub-community has relatively few samples in this survey. It is not clearly separated from the previous sub-community in terms of edaphic factors, although may perhaps be more usual on slightly drier sites than the *Eupatorium* sub-community. More important, it seems, is the association with management. The Typical sub-community appears to depend on more frequent management, usually annual mowing, whereas the *Eupatorium* sub-community is more commonly associated with 2-3 year cutting cycles (Rodwell 1991b). Traditionally both vegetation types were mown. Rodwell suggests that grazing would provide an analogous treatment, but Wheeler (pers. comm) has suggested that the trampling and dunging associated with grazing may steer the floristics of M24 closer to M22, especially on wetter ground. The compaction, increase in nutrients and surface eutrophication associated with grazing all favour *Juncus subnodulosus* over *Molinia*.

There is a much greater body of samples (406 in total) attributed to the other calcareous fen meadow, M22 *Juncus subnodulosus*-*Cirsium palustre* mire. This vegetation type is also maintained by annual cutting (and often by grazing) and occurs in situations with higher summer water tables and more elevated soil fertility than M24 Wheeler et al (2009). It too was mostly confined to the valley margins or to the narrow tributary valleys. Examples within the floodplain tended to be on nature reserves where it is deliberately maintained, or otherwise it tended to be very rank, species-poor and clearly progressing to tall herb fen. Extensive stands were occasionally recorded, such as at Burgh Common or in the headwaters of the Bure. The floodplain margin of the River Yare is another area with a significant resource.

The Typical sub-community of M22 was rather tall (70cm) and species-poor (mean species-number per sample of 15.2) and tended to be associated with very wet locations or those where management had been abandoned, the two perhaps being related. Stands recorded in this survey are often very heavily dominated by *Juncus subnodulosus*. Where abandonment was advanced, dense layers of rush litter smothered the ground. Three variants were identified within the sample group, all three being a relatively small sub-set of less than 15 samples each. They were characterised by *Carex nigra*, *Juncus effusus* and *Juncus acutiflorus*, suggesting a mild transition to poor-fen vegetation types. *Juncus effusus* is more frequent when compared to the reference NVC communities across this survey in a wide array of vegetation types.

With nearly half of all samples, the *Briza media*-*Trifolium* spp. sub-community was the most frequent kind of M22 in the Broads. Grazing appeared to be the most common treatment type. It is the richest of all of the sub-types and the sward one of the shortest. Notable sites are the valley margin pastures of the Yare and the great swathe of M22b at Burgh Common.

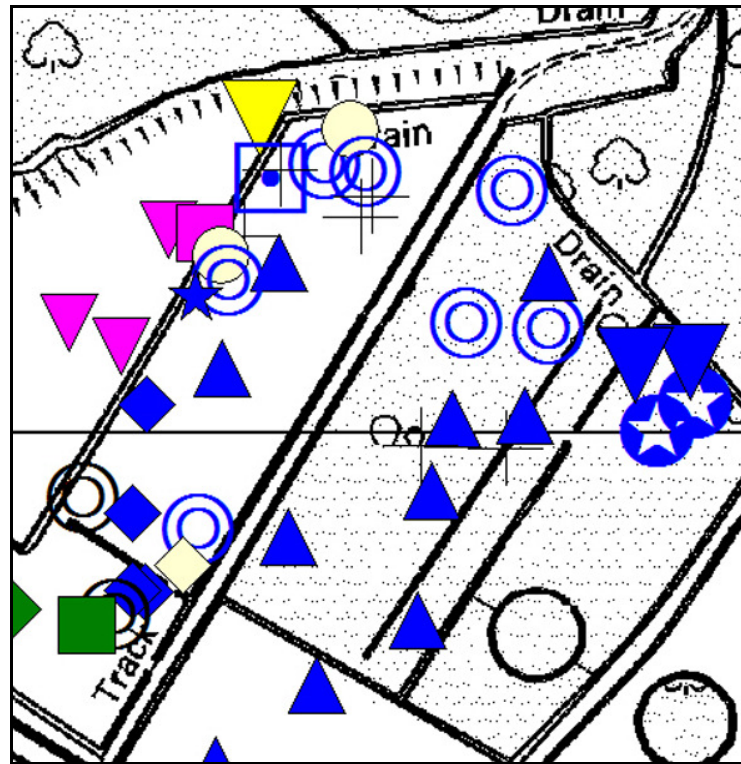
Increasing wetness marks the transition to the *Carex elata* sub-community, characteristic of swampy hollows and occluded foot drains with relatively high and stable summer water tables. This small sample set included a number of particularly wet stands where *Carex acutiformis* had largely replaced *J. subnodulosus* and where *Carex elata* was co-dominant. These stands appear to be transitional to swamp and tall herb fen.

The *Iris* sub-community is perhaps the classic floodplain M22 type, formerly much more extensive in Broadland and most characteristic of deeper peats with fluctuating base rich water tables. Stands of this vegetation type are still frequent (88 samples were recorded) and were characterised by a range of tall herb fen species often associated with S24.

It was especially difficult to separate M24 and M22 as their floristics seemed to intergrade. Rodwell (199b) himself notes the difficulty of partitioning these two communities. M22 and M24 can co-exist in mosaics, as in some parts of the Yare valley margins (Figure 3). As the marsh here is more or less flat⁸ and all stands of vegetation receive the same grazing treatment, it is likely that the arrangement of communities here is related to variations in the character of the peat. Much of the M24 in the survey had very frequent and often abundant *Juncus subnodulosus*, so the momentum appears to be toward M22. If sites become wetter, grazing introduced or stocking levels increased, shifts from the more uncommon M24 toward M22 can be expected.

⁸ At least, to the eye. Small variations in the height of the marsh surfaces not apparent to the naked eye could be significant, and micro-topography cannot be ruled out as a significant factor.

Figure 3. Intergrading fen meadow communities on the northern margin of the Yare floodplain, Hasingham Marshes.



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Key

- | | |
|---------------------------------|----------|
| ◆ M22(a) | ◻ M23(a) |
| ▲ M22(b) | ◎ M24 |
| ▼ M22(d) | ★ M25(b) |
| ★ M22(a) <i>J. effusus</i> var. | |
| ✚ Unassigned | |

other symbols are swamp and tall herb fen

4.2.3 Base Poor Fen Meadows

Two types of base-poor fen meadows were recorded. The first is M23 *Juncus acutiflorus*-*Galium palustre* rush pasture, often containing abundant *Juncus effusus*. The vegetation included a range of species typical of base rich fens, and fewer species indicating low nutrient situations, such as *Molinia*, than the reference NVC type. It is considered by Rodwell (1991b) to be normally found at the opposite end of the climatic and hydrochemical spectrum to M22, being typical of the west of Britain on acid to near-neutral soils. Its presence and form in Broadland is therefore very unusual. It does not

appear to be located on valley-side sands and gravels but on floodplains or their margins where the peats seem to either be naturally more acid or have become acidified recently, perhaps through surface drainage and leaching. Historically, this vegetation type has not been well documented in the Broads, although whether this is because it has been overlooked or has developed more recently is not known.

The second more acid mire community is M25 *Molinia caerulea*-*Potentilla erecta* mire. Only 19 samples were recorded, all within the *Anthoxanthum odoratum* sub-community. This is again a northern and western community not recorded in eastern England. It has the same relationship to M24 (its analogue on calcareous substrates) as M23 has to M22, and many of the same comments apply. It is generally found on substrates that are lower in nutrients, less compacted and more aerated than M23 (Rodwell 1991b). It was widespread, but especially common in the Thurne catchment.

4.3 Swamps and Tall Herb Fens

In the following account communities are described according to their position on the hydrosere. It should be emphasised that this is a very broad categorisation. It works well for sequences of pioneer swamps but is less helpful in the interior floodplain areas where past peat cutting can locally regenerate the early stages of the hydrosere. While the research of Lambert and co-workers has elucidated the early hydrosereal succession very clearly, particularly in the middle Bure and Yare, the more complex latter stages have only been partially disentangled by subsequent work, most notably by Wheeler and co-workers especially in the Ant. The hydrosere is therefore much more difficult to interpret for the landward parts of the floodplain.

4.3.1 Pioneer Swamps

Rodwell defines 21 swamp NVC communities of which 17 might have been expected in this survey⁹. Only two of the 17 were not recorded¹⁰, although many were infrequent. True swamps tend to be open water transition communities with above-ground water tables and associated with a variety of substrates which are generally unconsolidated or, in the case of some hover, entirely water. Relatively few species are able to tolerate these conditions. Consequently, swamp communities tend to be impoverished. This may be exacerbated by the competitive advantage of the few which can grow in such conditions. Dominance may be further enhanced by management treatments which are intended to favour productive growth and produce a “clean crop” of commercial species. Swamps occupy the early parts of the hydrosere, between aquatic communities of the Broads and the fens of the firm peats.

Stands of S1 *Carex elata* swamp were rare in this survey, as they were in the early 1990's (Parmenter 1995). This is a community of dyke edges and the margins of low nutrient fen

⁹ S10 *Equisetum fluviale* swamp and S11 *Carex vesicaria* swamp are restricted to the north and west of the UK. S15 *Acorus calamus* swamp and S16 *Sagittaria sagittifolia* swamp are rare communities with tiny numbers of samples defining them in the NVC, only recorded in fragments by past workers (e.g. Wheeler 1978).

¹⁰ S18 *Carex otrubae* swamp is an uncommon type, generally fragmentary and difficult to define, occupying the narrow zone between fen and mesotrophic grassland. It was defined with only a few samples in the NVC and may perhaps have been overlooked in this survey as no stands were recorded. S3 *Carex paniculata* swamp is discussed in the main text.

pools. Only three samples were recorded, all overwhelmingly dominated by the eponymous sedge. Although *C. elata* is a very common constituent of Broadland fens, where it may even be dominant, mono-dominant swamps appear no longer to be characteristic. The classic location, at least in East Anglia, appears to be around the margin of pingo ponds in the Brecks where water tables fluctuate. Superficially at least, analogous habitats appear to exist in the Broads, but Rodwell (1995) records no samples from here, describing it as an uncommon community in the UK. *Carex elata* swamps are not referred to in the accounts of seral succession compiled by Pallis and Lambert, although the community was recorded by Wheeler (1980a).

Many other swamp communities were recorded in small or fragmentary stands and/or in relatively few samples. They are S8 *Schoenoplectus lacustris* swamp, S9 *Carex rostrata* swamp, S17 *Carex pseudocyperus* swamp, S19 *Eleocharis palustris* swamp, and S22 *Glyceria fluitans*, the last being a water margin community more typical in the Broads of the foot drains and dyke edges within grazing marshes. All of the eponymous dominant species could be found within other swamps and tall herb fens, but mono-dominant stands, reflecting the particular habitat conditions usually typical of the early part of the hydrosere succession favoured by these species, were uncommon. At least one, S8 *Schoenoplectus lacustris* swamp, is recorded as characteristic of the very earliest hydrosere, preceding even *Typha angustifolia* in deeper waters (Lambert 1946, 1951, Lambert and Jennings 1951) and at one time forming a valuable commercial crop harvested from boats (Lambert 1965). Giller and Wheeler (1986) record it as a fragmented and sporadic precursor to all the four seres they defined for shallow turf ponds. This pioneering swamp type is now very rare. In this survey, all of these swamp communities were recorded in hollows and peat cuttings in the floodplain fens, not as true open water transition communities, which may explain their atypical floristics which included a wide range of fen species.

There were more but still modest numbers of samples from S14 *Sparganium erectum* swamp, a community typical of mineral substrates at the margins of ponds and rivers and in shallow eutrophic water. Rodwell (1995) indicates the community succeeds pioneering *Typha* swamps, occupying shallower waters, a sequence also recorded in the Broads (Lambert 1951, Lambert and Jennings 1951). In this survey, the vegetation type was restricted to hollows and edges of broader dykes and pools in fen compartments and away from peat substrates. The *Mentha aquatica* sub-community was the principle type recorded in this survey, being typical of the dryer parts of the hydrosere. The sub-communities representative of the deeper waters and less secure substrates were recorded in only a few stands. These vegetation types may be more common along the river margins, which were not extensively sampled. However, boat traffic in the Broads has greatly reduced the marginal vegetation of watercourses and led to the development of steep banks and deeper water (George 1992) which is inimical to the establishment of *Sparganium* beds.

S12 *Typha latifolia* swamp and S13 *Typha angustifolia* swamp were both comparatively rare in the survey, recording 34 and nine samples respectively. *Typha angustifolia* in particular was formerly the most characteristic pioneer species in much of the Broads, and an essential facilitator for later successional communities (Lambert 1951 and Lambert and Jennings 1951). Both *Typha* species grow in deeper water, up to 60cm, and can extend out some distance into a Broad if it is shallow. *Typha angustifolia* can also extend out via floating mats of rhizomes (unlike *T. latifolia*), particularly if the edge of the broad is

sheltered. In Lambert's studies, *Typha angustifolia* may have been more prominent in the early hydrosere because it is more tolerant of the low nutrient water that characterised the Broads at that time. Most samples from both communities were located within fen compartments, either on pool margins or in fen hollows. Samples recorded had a much broader range of fen associates than the reference NVC community type, again reflecting the sub-optimal habitats and the fen context in which they were recorded.

The recession of all of the marginal swamps in Broadland is discussed in Lambert (1965), George (1992) and Boorman et al (1979). It has affected *Phragmites* swamp¹¹ and *Glyceria* vegetation (discussed below) as well as the above swamp types. The marginal swamps appear to have been at their maximum extension around 1950-1955, but suffered a catastrophic decline through a rapid expansion of coypu numbers in the late 1950's. Coypu grazed the foliage and the rhizomes, breaking up the fragile mats. By 1965, the pioneer swamps in Broadland had been "...virtually destroyed.." (Lambert 1965). The damaged swamps were further affected by increasing boat traffic and associated impacts on the water margin, the exposure of the margins to wave erosion, and for some species associated with low nutrient waters, the worsening water quality. Perhaps more significantly, these processes prevented recovery of the swamps when the coypu were themselves exterminated.

4.3.2 *Glyceria maxima* swamp and the Yare valley

S5 *Glyceria maxima* swamp was once an extensive community in more eutrophic situations, and was particularly characteristic of the Yare floodplain (Lambert 1946) where it was an important pioneer species within the hydrosere. Results of this survey confirm the widely held view the species has undergone much decline and the plant communities of the Yare have exhibited very significant changes since 1946.

The Yare is freshwater tidal, with a daily range reported by Lambert of 20-30cm at that time. This movement, combined with a dense network of dykes, ensured constant circulation of water around the broads and within the fen compartments. According to Lambert, these conditions provide optimum growth for *Glyceria*. Its more vigorous tillering, and the earlier emergence of its shoots in spring, gives it a significant competitive advantage over reed. Its growth over open water or liquid muds as hover can greatly outstrip reed under suitable conditions. This is in part due to *Glyceria*'s ability to form near-horizontal stems that float in water, requiring no mechanical support, whereas reed growth is predominantly upright and requires a more stable substrate to prop up the swamp. *Glyceria* also has more freely proliferating stems, which in the procumbent form in watery hover remain winter-green and are consequently available for growth year-round (Lambert 1947). Hence, in the right conditions, rates of extension of the *Glyceria* swamp greatly exceeds that of reed. *Glyceria* maintains its competitive advantage within fen compartments where water circulation remains free, and extensive stands were mapped by Lambert (1946) on the Yare floodplain.

However, because of its ability to anchor into firm substrates at greater depth than *Glyceria*, reed is more resistant to mechanical damage by scour. It dominates where river

¹¹ . In NVC terms the open water pioneer reed vegetation would be S4a, the *Phragmites* sub-community of *Phragmites australis* swamp. The range vegetation types within S4 are much wider than pioneer swamps and are therefore discussed below.

and tidal flows are too strong for the weak *Glyceria* hover, which is susceptible to mechanical break-up. Hence, Lambert (1946) describes reed swamp forming a protective band of pioneer vegetation in exposed areas, behind which *Glyceria* swamp proliferates.

It was assumed that the primary role of water circulation was to constantly re-supply the fens with river-derived nutrients. Under such circumstances, the morphological adaptations and growth patterns of *Glyceria* were fully utilised to the exclusion of all other species. Lambert (1946) provides evidence of this in the broad floristics for three of the vegetation types she examined, dominated by either *Glyceria*, *Phragmites* or *Juncus subnodulosus*. The *J. subnodulosus* community, a minor component of the floodplain, occupied positions even further from free-circulating waters, deep in the compartment interiors or towards the highland margin. As the flora changes through the three communities, and distance from the water margin increases, so the range and frequency of species indicative of eutrophic species declines. As *Urtica*, *Galium aparine* and *Epilobium hirsutum* decline with the *Glyceria* swamp, there is a parallel increase in mesotrophic fen species in the *Phragmites* swamp, and eventually a preponderance of low-growing species typical of infertile situations such as *Molinia*, *Parnassia palustris* and *Menyanthes trifoliata* which characterise the *Juncus* fen. There is clear evidence of nutrient depletion across the floodplain.

However, from their detailed studies of a short transect of reed and *Glyceria* swamps on a part of the Surlingham Marsh, Buttery and Lambert (1965) and Buttery et al (1965) concluded that the importance of water circulation was not in re-supplying *Glyceria* with nutrients, but in maintaining high redox levels in the rooting zone. Where such conditions prevailed, *Glyceria* was not nutrient limited and had the competitive advantage over reed. In the compartment interior, water circulation decreased as did oxygenation of the rooting zone. Morphological adaptations of reed in the rooting zone meant it was better able to absorb nutrients in low oxygen conditions and hence competitive advantage passed to reed. Measurements of macro-nutrients along the transects showed no decrease with distance from the water margin. Their observations did not explain the apparent decline in associate species characteristic of eutrophic conditions in these fens. It is possible that at only 120m or so, their transect was too short to detect nutrient decline across a wider floodplain. It is quite possible that in the valley as a whole, there is a gradient of both nutrients and redox in the rooting zone, both factors affecting the distribution of dominants and the associated flora.

In other river catchments with minimal tide-driven water circulation, or in parts of the Yare which are locked out from such water movement, *Phragmites* out-competes *Glyceria*. Lambert's maps of 1946 show the greatest concentration of *Glyceria* around principle dykes, sheltered broad margins, already-skimmed over water bodies or fen compartments with a dense network of open dykes. In skimming-over dykes, *Glyceria* itself restricts water movement which paves the way for succession by *Phragmites*. Lambert (1946) neatly summarises this succession by mapping the transition of clear water dykes to *Phragmites* fen through a *Glyceria* stage.

In stark contrast to the situation described by Lambert, extensive stands of S5 vegetation on the floodplain were very rarely recorded in this survey. Less than 50 samples were attributed to *Glyceria maxima* vegetation, most still from the Yare. Those that were recorded were not typical of the reference NVC community or of the very species-poor stands described by Lambert (1946), having very frequent reed and often a more diverse

range of fen associates. It is generally accepted that *Glyceria maxima* vegetation has declined significantly in the Yare. It has been speculated that increased duration, intensity and frequency of flooding may be partly to blame (Entec 2007). A specific study of the vegetation of Wheatfen (Entec 2008) found that the vegetation did indicate the site may be wetter, but also found an increase in *Glyceria* compared to 1934. The authors provided many caveats to the study.

Abandonment of management, which includes dereliction of dykes, may also be a critical factor in explaining changes in the Yare. Historically the Yare marshes were managed intensively through annual summer mowing, a practise which had already greatly declined by the 1940's. *Glyceria* can sustain three crops per summer without being depleted (Lambert 1946), while reed is excluded by a single cut each summer. This relates to growth morphology – *Glyceria* sends up a constant supply of new shoots throughout the year, replenishing any lost in cropping, and is a very vigorous species with a much longer growing season (Buttery and Lambert 1965). *Phragmites* has but a single episode of shoot creation, which occurs much later in early summer, hence its vulnerability to summer cropping. Hence cessation of mowing is likely to favour reed, at least allowing it to build frequency and abundance if not exclude *Glyceria* altogether. The succession will be accelerated by the overgrowth of the dykes which would accompany abandonment of management, reducing circulation of water around and across the marsh¹². Marshmen quoted by Lambert recalled that by 1946, following a significant decline in mowing, the fens in the Yare were already significantly more reedy than in the past. The progressive *Glyceria*-reed succession across fen compartments consequent upon abandonment was modelled in an elegant series of drawings by Lambert (1946).

It seems probable that the decline of the Yare *Glyceria* swamps is likely to be due primarily to decline in management. The original conditions which favoured *Glyceria* – tide-driven circulation of water – are if anything likely to have increased since 1946 as the Yare has become both more eutrophic and experiences greater water level flux. The impact of increased flooding on redox at the rooting zone is unclear. Increased daily flushing will improve redox conditions, but higher residence times of floodwater could reduce redox compared to natural tidal cycles, especially if prolonged summer flooding is involved. Reduced redox may act in tandem with abandonment of management to amplify the switch to *Phragmites* fen, at least in some “swampy” parts of the floodplain. Increased flooding combined with raised nutrient levels and cessation of management would also explain the increase in eutrophic fen and pond sedge vegetation described below.

4.3.3 Swamps of the Early to mid Hydrosere

Stands of S3 *Carex paniculata* swamp were not recorded at all in this survey. The absence of S3 may be an important indicator of wider changes in the Broads. It is discussed by George (1992), who was concerned at the decline of what he considered a classic Broadland fen community. It was a central phase of the Broads hydrosere, invading pioneer swamps of *Typha* and *Phragmites* (Lambert 1946, 1951, Lambert and Jennings 1951) on very loose peats or even hover. This can result in reasonably diverse fen vegetation which included aquatics in the pools between tussocks (Lambert 1965). Wheeler (in litt. 2010) comments that the community was present when he sampled the

¹² Although the degree to which surface flooding overcomes this effect is not known and probably varies considerably across the floodplain.

Broads fens in the late 1970's, and describes “..extensive areas of the community...” on the west side of Barton Broad (Wheeler 1978). As with *C. elata*, the tussocks of *C. paniculata* were sometimes dominant in other fen communities recorded during the current survey, but these were richer vegetation types of the mid-hydrosere on firm peat. Such vegetation types were not referable to S3. Parmenter (1995) recorded no true S3, only 0.14ha of S3-S24a intermediate.

S3 swamp is itself a transitional part of the hydrosere, giving way to more diverse fen communities, whose species often use the sedge tussocks as a substrate. The richer tussock sedge swamp types are transitional to the *Carex paniculata* sub-community of S24 discussed below¹³. The tussocks of sedge were also ideal rooting media for trees, particularly alder, even in the wettest fen types. S3 therefore provided the opportunity for wet woodland to develop directly along the broad margins and in the heart of the pioneer swamps, developing a uniquely Broadland swamp woodland first described by Jennings (1946, 1951). This kind of fen was generally not mown (and therefore the trees not controlled) because the tussocks and treacherous ground made it impossible. Consequently, scrub overgrowth has always been a cause of loss of S3 and other vegetation types rich in tussock sedge. Latterly, S3 appears to have been lost through smothering by eutrophic fen species (George 1992), although the reason for this is not clear. Of the three post-reed swamp successional stages (the others being *Cladium* and *C. acutiformis*), *C. paniculata* swamp is associated with situations closest to river and broad margins with greatest circulation of water (Lambert 1946, 1951) and may therefore be suffering the consequences of the well documented eutrophication of Broadland waters (Moss 2000). New stands of *Carex paniculata* swamp are not being created because of the loss of the pioneer swamps into which they invade. Consequently, because of eutrophication, scrub encroachment and the lack of regeneration, the evidence of the current survey is that “...the demise of Broadland's Tussock Fen...” so lamented by George (1992) may be nearing completion.

4.3.4 Pond Sedge Vegetation

Swamps and fens dominated by the pond sedges (*Carex riparia* and *Carex acutiformis*) occupy an obscure place in the Broadland hydrosere. Both species can be prominent on the water margin, but are not true pioneer swamps in the sense that they cannot withstand deep prolonged summer flooding or extend on floating mats across open water. Neither do pond sedge swamps appear to be part of the accepted cannon of later hydrosere swamps and tall herb fens. Rarely has S6, S7, or other vegetation strongly dominated by either sedge, been explicitly recognised as major fen communities by wetland ecologists. There is the slight space given to the two NVC swamp types in Rodwell (1995). Lambert (1951) recognised a “*Carex acutiformis* sere” along the Bure valley, an alternative to *Carex paniculata* in the hydrosere in locations where water movement around fen compartments was less. She did not present floristic tables of this vegetation (so her vegetation type cannot be compared to the communities described here), and their representation in the stratigraphical-vegetational transects compiled by Lambert and Jennings (1951) is very modest. She later refers to *C. acutiformis* as occupying

¹³ It is possible that some of the richer samples of tussock fen recorded by Wheeler and Lambert would in fact be placed in *Carex paniculata* sub-communities of S24 or S25 in a purely NVC treatment. S3 may be more tightly circumscribed than their communities, which may in part explain the greater abundance of tussock fen in their accounts. S24a was still commonly found on water margin sites (see Figure XXX).

“...only a minor role...” in the hydrosere (Lambert 1965). Parmenter referred to S6 and S7 as “infrequent”, recording a combined area of only 10.2 ha. In terms of the abundance of the two species in other communities, Rodwell (1995) records only footnotes in the accounts of S24, S26 and M22, but otherwise the vegetation has not had much recognition. It has fared better in Europe where at least the *Caricetum ripariae* is well recognised Rodwell (1995).

This survey has recorded many samples attributable to S6 *Carex riparia* and S7 *Carex acutiformis* swamps. It has also identified two previously unrecognised communities dominated by the pond sedges, and also new sub-communities of S4 *Phragmites australis* swamp and S26 *Phragmites-Urtica* fen. A summary of the pond sedge vegetation is given in Figure 4. The arrangement of communities along a fertility axis uses Ellenberg’s value for fertility and is provisional. Two main points emerge from the diagram:

- That there are many more vegetation types dominated or characterised by the presence of one or more of the pond sedges than previously recognised.
- That the pond sedge communities are by and large associated with the eutrophic end of the fertility scale.

The total area of pond sedge vegetation shown on Figure 4 is 311.2ha, or 18% of the fen resource. Whether the prominence accorded to these sedge communities in this survey reflects a real and significant expansion of this kind of vegetation, or the under-sampling of pond sedge in previous surveys, is not known for sure. Parmenter’s (1995) survey is difficult to compare because her unique plant communities are difficult to correlate to those in Figure 4. The abundance and frequency of the pond sedges is so marked in the current survey that it seems unlikely they would have been overlooked in previous work, but direct evidence of change remains elusive.

In the *Results* section, two stands of S6 *Carex riparia* swamp have been identified on the basis of different sets of associates, with S6(1) being the closest fit to the NVC reference type. They both have a much higher frequency of *Phragmites* than the NVC type, although the sedge is always very dominant. The stand of S7 *Carex acutiformis* swamp similarly carries frequent reed, and is richer in species than the reference type. These differences may reflect the fen context in which the community resides. Rodwell (1995) indicates most stands of S6 and S7 are in open water transitions rather than within fen compartments, which is the usual location in this survey. Tall herb fen species (and especially reed) that surround the pond sedge communities in the Broads may readily invade the stand. Alternatively, the communities described in this survey may have arisen through the invasion of pond sedges into other fen vegetation types. Rodwell (1995) notes *Carex acutiformis* is a particularly aggressive species which can invade fields where drainage is not maintained. Lambert (1965) when discussing the minor role of *Carex acutiformis* in the Broadland hydrosere suggests it may be much more prominent where fen communities have not been cut for many years. Many of the sites where either pond sedge species was strongly dominant in this survey appeared to experience little management, and this is the common experience of the field surveyors in sites all around East Anglia. The evidence suggests that it is pond sedge that has invaded other fens, not the way around, consequent upon dereliction. However, again in the absence of direct monitoring data the evidence remains circumstantial.

Figure 4: Summary of vegetation types recorded in this survey dominated by or with a strong component of either *Carex riparia* or *Carex acutiformis*. Communities in red are newly proposed types in this survey. Thick lines indicate vegetation characterised by dominant sedge, thin lines where the sedge is a principle component either by frequency or abundance and a dashed line where the sedge is significant. The number in brackets is the Ellenberg value for nitrogen.

				OV 26 <i>Epilobium hirsutum</i> (b) <i>Phragmites-Iris</i> sub (6.2)	
M22 <i>Juncus-Cirsium</i> fen meadow. (b) Typical sub. (c) <i>Carex elata</i> sub. (d) <i>Iris pseudacorus</i> sub (4.3)	S26 <i>Phragmites-Urtica</i> BS(f) <i>Carex spp.</i> sub (5.4)	BS2 <i>Carex acutiformis-Filipendula ulmaria</i> swamp. (5.7)	S6(1), S6(2) <i>Carex riparia</i> swamp (6.2)	BS1 <i>Phragmites-Carex riparia</i> swamp (6.3)	
S24 <i>Phragmites-Peucedanum</i> intermediate (b) <i>Glyceria</i> -(c) <i>Symphytum</i> (4.5)	S24 <i>Phragmites-Peucedanum</i> (b) <i>Glyceria maxima</i> sub (5.1)	S4 <i>Phragmites</i> swamp BS(h) <i>Carex acutiformis</i> sub (5.7)	S7 <i>Carex acutiformis</i> swamp, S6-S7 Intermediate <i>Carex</i> swamp (6.1)	S26 <i>Phragmites-Urtica</i> BS(e) <i>Calamagrostis</i> sub (6.3)	S26 <i>Phragmites-Urtica</i> (d) <i>Epilobium hirsutum</i> sub (6.4)
Mesotrophic					Eutrophic

It is not clear why one pond sedge is ascendant over the other in any particular situation. Ecological amplitudes of the two species are not well understood (Jermy et al 2007). Field experience suggests *Carex riparia* tends to be more prominent closer to the river or broad, while *C. acutiformis* tends to be more characteristic of the centre and rear of the floodplain. Conditions close to the river are likely to be more “swampy”, with more frequent inundation and for a longer duration than interior or rear parts of the floodplain, although local topography can greatly modify this general picture. There may also be changes in water quality with distance from the river which the sedges may be responding to. However, there is clear overlap in their distribution and in many samples the two sedges coexist, in both the Intermediate S6-S7 community, and in tall herb fens where the sedges can be a significant components.

Pond sedge vegetation can be extremely variable, particularly in the Intermediate S6-S7 community where either can be dominant. Samples can be very species-poor through to quite species-rich.

Vegetation rich in pond sedges has given rise to two new communities not recognised by the NVC. The first is the BS1 *Phragmites australis*-*Carex riparia* vegetation, generally dominated by reed but with a dense under-storey of *C. riparia* which can co-dominate in places. There are a range of tall herb fen species and together these characteristics place the community outside of S4 *Phragmites* reed swamp¹⁴. The second new community is BS2 *Carex acutiformis*-*Filipendula ulmaria* fen. It is characterised by dominance of the sedge with frequent and sometimes abundant medium-height fen species, particularly *Filipendula*. This vegetation type is a bridge between swamps and tall herb fens particularly S25 *Phragmites*-*Eupatorium* fen. There is no clear pattern, in terms of location or environmental conditions, associated with BS1 and BS2. New sub-communities of S4 and S26 defined by their richness in the pond sedges are discussed more fully under their parent NVC communities.

As well as an association between the pond sedges and reduced or abandoned management, there may also be an association with elevated nutrients. This is implied by their location (such as the Yare floodplains where many of these vegetation types are found) and by the inclusion of eutrophic indicators such as *Urtica* in a number of the stands. It is difficult to disentangle management and nutrients. The pond sedges are much less prevalent in the interior of fens in catchments such as the Thurne and Ant, but they can still be prominent even here in unmanaged stands of for instance S24. Finally, pond sedges may be responding to wider hydrological changes unrelated to dereliction of internal ditches, such as the increase in flood frequency and duration in the Yare described above. Changes to management, elevation of nutrients and changing hydrological regime are perhaps the three most important environmental changes operating in the Broads today, and the pond sedges may be important signifiers of these changes. However, the evidence for all of the changes and their causes discussed here is circumstantial and until direct evidence is adduced, these must remain preliminary conclusions.

¹⁴ A new pond sedge based sub-community of S4 has been described but this is wholly dominated by reed and very species-poor. The sedge in this case however is *Carex acutiformis*.

Other vegetation types recorded in the survey can be very rich in these species. The overall effect is to produce what appears to be a rather ambiguous treatment of pond sedge vegetation in the classification, and a blurring of the definition of other communities. The phytosociological relationships of some of these communities are not clear, and the relationship between them and a range of environmental variables is similarly obscure. Clearly, there are a range of issues surrounding pond sedges in the Broads fens which require further research. A much improved understanding of the autecology of the two sedges would be particularly helpful.

4.3.5 Sedge and Reedbeds: S2 and S4

The two remaining NVC swamps are S2 *Cladium mariscus* saw-sedge swamp and S4 *Phragmites australis* reed swamp, and their related vegetation types. Only reed communities tend to front broads and rivers as swamp pioneers, although as described above, this reed front has undergone severe recession. Lambert (1951, 1965) refers to *Cladium* as a secondary swamp dominant, following *Phragmites* relatively rapidly where stands are isolated from the river¹⁵. Pioneer colonisation of open water by *Cladium* is restricted to small and shallow peat cuttings with stable water levels. It rarely colonises open water but can sometimes form hover over liquid muds (see for instance descriptions of the Ant valley, Wheeler 1978).

S2 and S4 are the principal swamp colonists of shallow turf ponds (up to 70cm deep) found within floodplain. Although superficially these mini-broads within the floodplain interiors appear to re-start the hydrosere, Giller and Wheeler (1986) demonstrated that the successional pathways in these man-made hollows were often different to those of the main broads. The critical *Carex paniculata* sere and the much more minor *Carex acutiformis* sere Lambert described from terrestrialsing main broads were absent from turf ponds, while the mid-late successional *Cladium* communities were unique, reflecting the particular hydrology of the turf ponds. All turf pond seres usually started with a fragmentary *Schoenoplectus lacustris* stage. The subsequent succession of a particular hollow appears entirely determined by the substrate exposed by the digging. On peat, *Cladium* quickly assumes dominance, which is maintained throughout the sere of that name. The *Cladium* sere then succeeds to species-rich S24 communities, with certain floodplain margin sites developing the very rich *Peucedano-Phragmitetum caricetosum* (described more fully under S24). The *P-P caricetosum* then succeeds to drier S24 sub-communities. On clay, the succession is to one of *Typha angustifolia* or *Phragmites*. Either of the latter two could then progress to one of three final *Phragmites* seres, either reed alone, or with *Juncus subnodulosus*, or with *Cladium*. These three seres are all relatively species-poor, with the *Phragmites-Cladium* sere progressing to dense but species-poor sedge beds if managed by summer cutting.

¹⁵ Lambert (1951) proposes three dominants of the early hydrosere which follows *Typha angustifolia* and *Phragmites* in the succession of former broads; *Carex paniculata* swamp, the most common outcome, on sites which experience high rates of water circulation from the river, *Cladium* on sites which experience low or no circulation of water from the river; and a small and ill-defined *Carex acutiformis* sere which lies between the two. As with the *Phragmites-Glyceria* relationship on the Yare, water circulation may determine fertility, the most likely explanation for the three succession pathways.

Cladium mariscus swamp

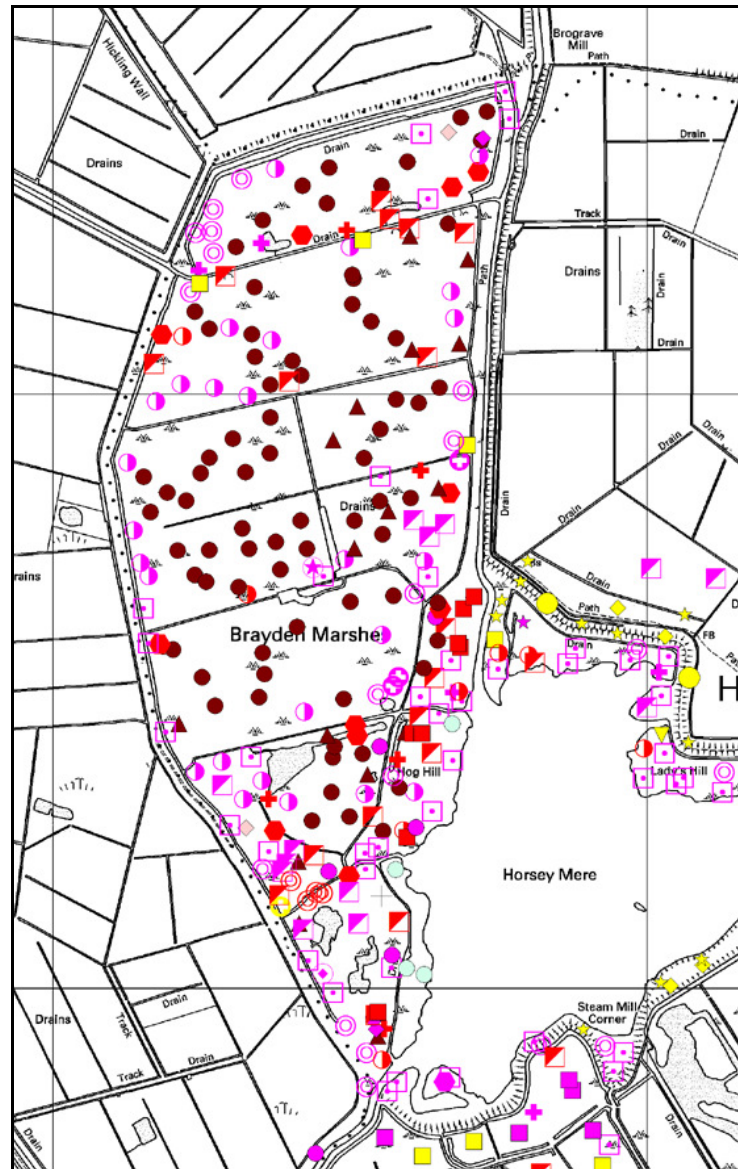
S2 *Cladium mariscus* swamp, where the sedge is the only dominant and the associated flora is both infrequent and of low cover, is a valuable commercial thatching crop which is harvested every 3-5 years. The dense growth and persistent litter associated with this species strongly suppresses the associated flora. S2 swamp is mostly restricted to either former turbaries (the wettest examples with greatest expression of wet fen species) or in swampy hollows in the more calcareous and base rich mowing marshes (which tend to be denser and more species-poor vegetation types). Examples of the former are seen at Catfield Fen in the Ant valley, while the latter is best seen in the extensive stands of the Brayden Marshes in the Thurne. *Cladium* may be very dense in other fen communities, but these tend to have much broader floristics and be typical of the undug and drier surfaces of the mowing fens.

S2 *Cladium* swamp was rather uncommon (vegetation types with abundant *Cladium* were more common and are described below), with only 144 samples of this iconic community recorded in the whole of the Broads. This is just 2%. Most of these stands were rather small and set amid a variety of other communities. Stands of S2 tend to have rather sharp boundaries, readily identifiable on aerial photographs. This may reflect their occurrence in topographic hollows, such as shallow peat cuttings. Such boundaries may also have been emphasised by the different cropping treatment applied to the *Cladium* and the adjacent mixed fen communities.

Stands can be very species-poor, and only the *Cladium* sub-community was recorded during this survey. Some samples from Catfield Fen and other places included calcareous pools with charophytes, *Utricularia* spp., and a few other aquatics such as *Potamogeton coloratus*, and were very similar to very wet *Cladium* vegetation described by Wheeler (1978) at Catfield. However, the associated aquatic flora was not sufficient to place it in the S2b *Menyanthes* sub-community which appeared not be recorded in this survey, except in intermediate form with S25.

Phragmites is much more common in this vegetation than in the reference NVC type. *Cladium* is generally felt to favour lower nutrient situations than reed fen, hence the occurrence of frequent *Phragmites* may suggest an uplift in nutrients, although whether this reflects a historical trend is more difficult to say. Certainly at Brayden Marshes, the view of John Buxton (land owner) and of other workers in the Broads is that these very extensive stands of *Cladium* have become invaded by reed in recent decades. Field observations during this survey suggested reed invasion was particularly strong along the dyke margins, associated with recent dredgings, and declined toward the centre of the compartment. This is borne out by the survey results where the core of the compartments carries S2a *Cladium* swamp but the margins support either the newly described *Cladium* or *Solanum* variants of S4a *Phragmites australis* swamp, *Phragmites* sub-community (Figure 5). Even in the centre of the compartments the sedge was observed to be rather weak, and in places moribund. The anecdotal evidence suggests that these extensive sedge beds do appear to be undergoing significant change.

Figure 5: *Cladium* (brown symbols) and *Phragmites* communities (pink symbols) on the Brayden Marshes.



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Key

- S2(a)
- S4(a) *Cladium* variant
- S4(a)
- ◻ S4(a) *Ag. stolonifera* variant
- ⊙ S4(b)

It is also possible that reduced intensity of management may be responsible for the changes. Many stands of *Cladium*, especially the less accessible and smaller stands of least commercial interest, have had reduced cropping regimes, a decline noted even in the 1960's (Lambert 1965). The southern compartments of Brayden Marshes have not been managed for sedge for some time. Summer mowing reduces *Phragmites* in favour of *Cladium*, hence its cessation is likely to encourage progression to reed fen.

Most of the S2 vegetation is to be found in the Thurne, with some in the Ant and uncommonly in the Bure. The Ant and the Bure have much *Cladium*-dominated vegetation, but this tends to be saw-sedge dominated tall herb fens (S25c and S24f and g) rather than the species-poor swamps discussed here. The Yare and Waveney have very little *Cladium* vegetation of any sort.

There were rather more samples of a community intermediate between S25c, the *Cladium* sub-community of *Phragmites-Eupatorium* fen, and S2 *Cladium* swamp. Still dominated by sedge, and often still managed as a crop, these stands have much more *Phragmites* and a greater development of understorey associates, particularly *Juncus subnodulosus*, in what is clearly a transition between the swamps and the tall herb fens.

A clear link between S2 *Cladium* swamp and S4 *Phragmites* swamp is a new *Cladium mariscus* variant of S4a, the *Phragmites* sub-community of *Phragmites australis* swamp. This variant describes swamp vegetation that is strongly dominated by reed (hence its inclusion in S4) but with a constant under-storey of *Cladium*. There is little else other than occasional sprawlers and a little *Juncus subnodulosus*. This is a previously undocumented vegetation type, but whether it has arisen through reed invasion of *Cladium* or vice-versa is not known.

Phragmites australis swamp

Perhaps surprisingly, the swamp community which shows most variation in terms of sub-communities and variants is the S4 *Phragmites australis* swamp. Traditionally considered by botanists to be a rather uninteresting mono-dominant reed swamp, this survey has shown that at least in the Broads, this can include a very diverse range of vegetation types which can harbour plant species and communities of conservation interest.

S4(a) *Phragmites australis* is the poorest of the sub-communities, generally with 3-4 species in a 10 x 10m sample. It is wholly dominated by a tall and dense canopy of reed. In this account, it has been divided into a number of variants. The wettest examples (nearly 70% open water), under the densest reed canopy, is the *Lemna* spp variant. The duckweeds, mostly *Lemna minor*, occupy the shallow open water or in later summer, the wet bare mud. Few other species exist, although water margin and aquatic species are well represented at very low frequency. The next wettest vegetation type is the *Cladium mariscus* variant, discussed above, perhaps occurring on more calcareous, lower nutrient substrates than other variants. The third variant is the *Solanum dulcamara* vegetation, the driest of all with the least dense reed canopy. The range of associates, all very infrequent, are generally representative of dryer situations and include a range of non-fen species. It often seems to be located on dyke edges where peaty slubbings are deposited. The final variant is marked by abundant *Agrostis stolonifera* under dense reed, with little else. This occupies slightly more brackish conditions, either where there is seepage through the river wall or where underlying silty clay has been exposed.

There is a step up in species-richness to the other sub-communities, but this step is modest, to around 7-8 species per sample¹⁶. The sub-communities are consequently marked by a more diverse range of associates. Two of the reference NVC sub-communities were recognised, but to fully describe the variation in reedfen, a further five new sub-communities were described in this survey.

A large body of 300 samples has been attributed to S4b, the *Galium palustre* sub-community, with constant *Galium palustre* plus a few other rich fen species at low frequency. This has been referred to in this report as the Typical variant. This is a wet reed community, so *Lemna* species and the ubiquitous *Solanum dulcamara* are regularly present. A new *Agrostis stolonifera* variant, with an additional 142 samples, has been defined on the basis of constant and abundant *Agrostis stolonifera* making a grassy ground. This variant is slightly richer than the typical S4b community with a shorter, more open reed canopy and less litter. It presumably has similar habitat connotations as the *Agrostis stolonifera* variant of S4a.

There are a substantial number of samples from S4d *Atriplex prostrata* sub-community¹⁷. This is a community associated with brackish conditions, more so than the new *Agrostis stolonifera* variants of S4a and S4b, as indicated by the presence of high saltmarsh species. In all three variants of S4d¹⁸, a thinning and more stunted reed canopy overtops a flora which includes components of both saltmarshes and freshwater fens. The *Agrostis stolonifera* variant represents the higher elevations with least frequent inundations of brackish water, while the *Puccinellia* variant, more frequently exposed to brackish water, supports a wider range of mid-level saltmarsh species. These are communities mostly of the river faces of reed fens in the lower Waveney and Yare, washed by tidal salt incursions. There are also some examples of this vegetation behind leaky river walls, especially in the Thurne catchment.

The first of the newly proposed sub-communities, S4 BSe *Utricularia vulgaris*-*Potamogeton coloratus*-*Hydrocharis morsus-ranae*, is rare (with only 17 samples) and highly distinctive. This is the wettest of all S4 vegetation types with 84% open water. The community is characterised by aquatic and semi-aquatic species associated with low nutrient and base-rich water. The dominance of *Phragmites* in this habitat suggests management to promote dense reed either for conservation¹⁹ or commercial reasons. The associated flora, with its connotations of low nutrients and base-richness, suggests that were this summer-mown, a much richer fen flora could develop.

The second new vegetation type within S4 is the BSf *Carex acutiformis* sub-community. It is also a wet fen type with 78% cover of open water. Here, reed is dominant, but the lower tier has abundant *Carex acutiformis* and a range of wet fen associates at low frequency. In common with other swamps where pond sedge is unusually prominent, this sub-community may indicate situations where drainage has become occluded and management intensity reduced.

¹⁶ Samples that are substantially richer mostly pass into the tall herb fen communities.

¹⁷ No S4c *Menyanthes trifoliata* sub-community was described during this survey. This may be considered analogous to the “missing” *Menyanthes trifoliata* sub-community of S2.

¹⁸ Samples were assigned to S4dii *Puccinellia maritima* variant, the S4diii *Agrostis stolonifera* variant or if they did not fit within one of the NVC reference variants, to the S4d sub-community as a whole.

¹⁹ Dense wet reed is an important habitat for protected breeding birds such as bittern.

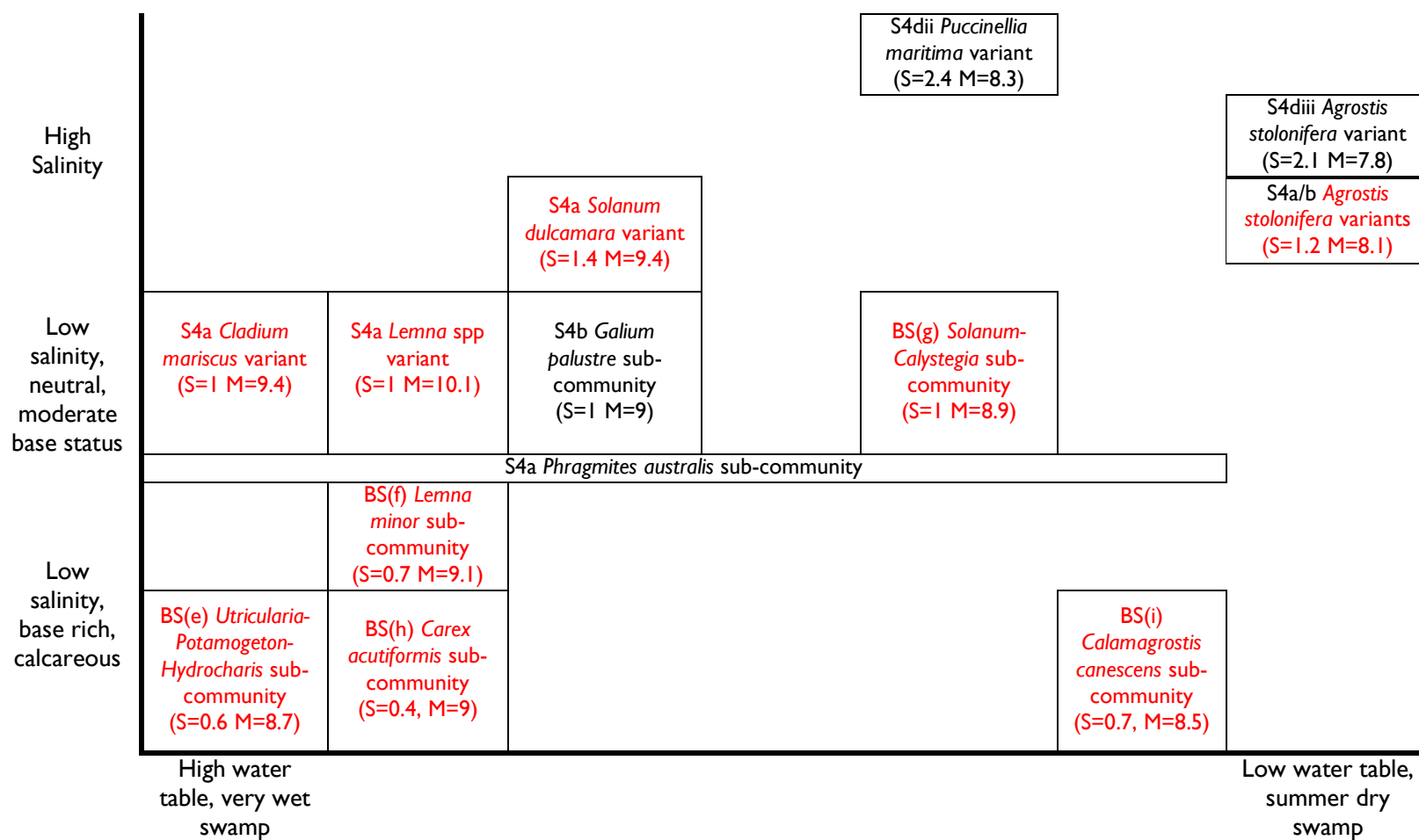
The S4 BSg *Lemna minor* sub-community has less surface water (52%) together with reed which is a little taller and denser than foregoing new sub-communities. The associates include many aquatic or semi-aquatic species, but these are less prominent than in the previous community and this element of the flora suggests more neutral conditions and perhaps higher nutrient levels. It is similar to the *Lemna* variant of S4a, but is much richer.

The last two new sub-communities of S4 are dryer swamp types with less than 20% open water. The S4 BSh *Solanum dulcamara-Calystegia sepium* vegetation is a typical reed community but on dryer ground, with frequent climbers and scramblers together with indicators of dryer fen at lower frequency. It is analogous to the *Solanum* variant of S4a, but the new sub-community is richer in fen associates. The second of the dryer sub-communities is the S4 BSh *Calamagrostis canescens* vegetation, with shorter and less dense reed. It is a relatively small group of 18 samples.

Figure 6 provides a provisional summary of the S4 vegetation types with their possible environmental relationships. The range of S4 vegetation types is not recognised in any former treatment of Broads vegetation. The new communities recognised by Parmenter (1995) are difficult to compare with the NVC and this survey.

Two swamp communities characteristic of mineral substrates in mildly brackish conditions are S20 *Schoenoplectus tabernaemontani* and S21b *Bolboschoenus maritimus* swamp, with only the latter recording many samples. They were mostly recorded in the lower reaches of the Waveney and particularly the Yare on river faces of the ronds where they are subjected to brackish water inundation. Some stands were recorded on the inside of leaky river walls or other places where saline water had penetrated the fen compartments in the Thurne catchment. The community had a very high frequency of reed, unlike the reference NVC types, perhaps reflecting the fen context of the current samples as opposed to the more common upper saltmarsh location of the NVC stands. Rodwell (1995) indicates that S21 (which had the bulk of samples in the Broads survey) is located in wetter and more saline situations than S4d *Phragmites australis* swamp, the *Atriplex* sub-community. Where it is mapped within or close to the latter, S21 is therefore likely to occupy hollows or lower parts of the reed rond.

Figure 6: Provisional Arrangement of Vegetation Types within S4. Those in red are new vegetation types proposed in this report. Values in brackets are Ellenberg values for salt and for moisture. Some of the wetter communities have been placed according to measured values of open water rather than Ellenberg's F.



4.2.6 Tall Herb Fens: The Mid-Late Hydrosere

The development of a much richer assemblage of associates beneath the upper tier of tall helophytes, and the tendency for the ground layer, lower tier and upper tier to blend together in more complex physical structures, signals the transition from swamps to tall herb fens.

S24: The Core Broadland Tall Herb Fen

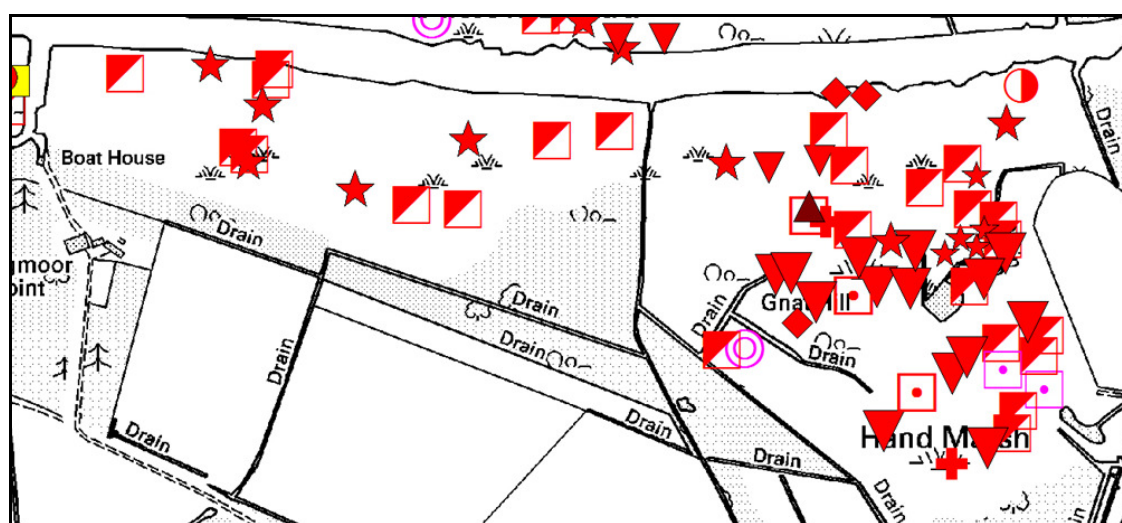
The second most abundant fen vegetation type (only marginally less in extent than S4 *Phragmites australis* swamp), and the most characteristic of the floodplains, is S24 *Phragmites australis*-*Peucedanum palustre* tall herb fen. Rodwell (1995) defines it largely through presence of a diverse mix of the following fen plants: *Juncus subnodulosus*, *Calamagrostis canescens*, *Filipendula ulmaria*, *Iris pseudacorus*, *Valeriana officinalis*, *Lythrum salicaria*, *Lysimachia vulgaris*, *Peucedanum palustre*, *Eupatorium cannabinum*, *Galium palustre*, *Mentha aquatica*, *Calliergonella cuspidata* and *Campylium stellatum*. While all of these species can be found in other fen and mire communities, it is their coexistence in particular stands which characterises the community. It is the core vegetation type of Broadland, and this kind of vegetation is rare outside of the area; there are examples in the remnant Fenland wetlands, mostly of the *Symphytum officinale* sub-community, and in the Somerset Levels and east Yorkshire.

Rodwell (1995) lists the main dominants as *Phragmites*, *Cladium*, *Carex paniculata*, *Carex elata* and *Glyceria maxima*. In under-managed *Cladium* sedge-beds, experience from this survey suggests *Myrica gale* can locally dominate, while the pond sedges *Carex riparia* and *Carex acutiformis* can also dominate a lower layer in some stands of other S24 vegetation, particularly the *Glyceria maxima* and *Symphytum officinale* sub-communities respectively.

The whole notion of dominance is much more difficult to apply consistently to S24 vegetation than to swamps or even other tall herb fens. Often, stands have no single dominant species, there being a more eclectic mix of abundant species. The pattern of dominance can shift spatially, even within the same compartment, and over short distances. This creates the illusion in the field of the presence of a range of communities. When this variation is simplified by the recording of vegetation data, which renders down heterogeneity in physical abundance to a few closely spaced numbers on the DOMIN scale, such stands can resolve into a single type of S24. This often leads to the feeling among surveyors that “something has been lost” when complex vegetation is simplified in this way. In reality the visual complexity of such vegetation may in fact simply confuse attempts to understand the underlying nature of the vegetation types. A key characteristic of S24 is, then, very complex structural heterogeneity in what may floristically be a surprisingly consistent vegetation type.

An example of this is Sutton Broad Fen, south of the dyke. (Figure 7). The site appears to be a very diverse mosaic of fen types, but following analysis these resolved into a few sub-communities of S24 together with samples intermediate between S24 and S25.

Figure 7. Plant communities of Sutton Broad Fen.



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Key	
◆ S24(a)	◻ S24(g)
▼ S24(d)	◻ S24-S25
★ S24(e)	
✚ S24(f)	

Because of the diversity of S24 vegetation, the determination of many of its sub-communities is much less driven by the principle dominant than is the case for the sub-communities of other NVC tall herb fen types. Only two of the sub-communities (*Carex paniculata* and *Glyceria maxima*) are derived from Rodwell's list of dominants. S24, more than most, still requires the corpus of associates to accurately place a sample within the span of sub-types. Often in the current data set, the species that has given its name to the sub-community may be reduced in frequency or even absent, but the overall stamp of the vegetation allows a sample to be placed within one of the seven reference NVC sub-communities.

S24 is central to an understanding of much of the fen vegetation of Broadland. The dominants of S24 are also largely those of the main swamp communities, many of which are pioneer vegetation types of the early hydrosere. S24 occupies the mid and later part of the hydrosere, when environmental conditions have been sufficiently ameliorated to allow the much wider range of fen associates to occupy the ground, a process assisted by reduced vigour in the swamp dominants. It is consequently the core vegetation type in the post-pioneer phase described by Pallis and Lambert in their successional studies, although it was not referred to by its NVC label. Some forms of S24, such as the *Carex paniculata* sub-community, are colonists of early pioneer vegetation, while others, such as the *Schoenus nigricans* sub-community appear to be associated with older phases away from

the leading edge of swamp, and on uncut peat surfaces (Rodwell 1995). Others, such as the *Cicuta virosa* sub-community are typical of old peat cuttings in the interior of fen compartments where the hydrosere has been regenerated by localised lowering of the peat surface.

S24 also provides a direct link to the species-rich and important mire communities found in Broadland. Frequent mowing converts S24 to one of M22, M23, M24 and M25, depending on the hydrology and chemistry of the substrate under the precursor community²⁰. Complete abandonment of management sees S24 proceed to one of the wet woodland types which is now all too common in the river valleys. Consequently, S24 could be regarded as at the intersection of many natural or anthropogenic successional relationships among the body of Broadland vegetation communities, particularly those of conservation concern.

Occupying the central position on the hydrosere, the resource of S24 is sustained by the generation of new vegetation from the progressive terrestrialisation of its swamp precursors. This newly formed S24 is then, supposedly, held in stasis by mowing management, at least historically²¹. Mowing management has to be sufficiently frequent to maintain tall herb fen, preventing transition to rank fen or even woodland, but not so often that tall helophytes are excluded and rushes and grasses take prominence, creating mires and fen meadows. Traditionally tall herb fen was mown on a 2-4 year rotation for a variety of marsh crops²². This practise had largely ceased by the 1960's (Lambert 1965), except for relatively small areas within nature reserves. The impact of cessation of mowing, changing cutting frequency or switching to other management regimes such as the fen harvester or grazing has been relatively little studied, which is surprising considering its potential implications for the fen resource.

All of the seven sub-communities referable to the NVC were significantly less species-rich than the samples described in Rodwell (1995). This dip in richness was usually around 15% but for the *Myrica gale* sub-community was closer to 25%. Part of the reason for the reduction in species-richness may be due to the accommodation within the sample groups in the current survey of vegetation plots which are marginal to this community or perhaps transitional to less rich communities. The larger size of samples used to compile the NVC communities may also enhance the richness of the reference NVC types. However, the possibility that Broadland fens have degraded compared to the late 1970's when the NVC data was recorded remains a strong possibility. Without direct and comparative time series data, it is impossible to elucidate the degree and cause of change any further.

²⁰ The opportunity to "create" M13 or M9 by mowing is much less certain, as both communities have very particular hydrological and hydro-chemical requirements. Variation in treatment cannot create these requirements.

²¹ The degree to which it is truly held in stasis is open to question. While mowing at the appropriate frequency will retain a particular sub-community of S24 as open and perhaps species-rich fen, there is no guarantee that in the very long term other vegetation processes not mediated by mowing would not shift the community to another vegetation type. Long term studies of stands of S24 under a stable management simply don't exist.

²² Lambert (1965) also recounts that these fens could be used for stock grazing, often after the summer cut. It is not clear from her text whether this includes all fens or mostly litter fens mown on shorter rotations for marsh hay.

Surprisingly perhaps, S24 is not ubiquitous in the Broads. Most samples were recorded from the Ant and from the Bure. The Yare had very little, as did the Waveney (although the latter has relatively little fen of any sort), and the Thurne only significant representation of the *Schoenus nigricans* sub-community.

The primary influence on determining the floristics of the seven sub-communities of S24 is the combination of hydrology and substrate chemistry, as described in Rodwell (1995), Wheeler (1978, 1980a), and Giller and Wheeler (1986). The *Carex paniculata* sub-community is a colonist of primary swamp fen, the community developing spontaneously over rafts of tall helophytes in waters of moderate nutrient status. It is presumably also generated by the ingress of S24 herbs into already established S3 *Carex paniculata* swamp, although this succession is not recorded by other workers. Stands of this community would historically have been “cleaned” of large sedge tussocks to ease mowing management (Lambert 1965), the cut tussocks finding a variety of local uses. In such circumstances, the sedge may persist as low-growing tufts, often abundant but less conspicuous, or may be wholly absent from stands. Cessation of management may once again allow such tussocks to reassert themselves in the vegetation.

S24e, the *Cicuta virosa* sub-community, is also an early coloniser of swamp, usually in swampy hollows and shallow peat diggings within fen compartments (Giller and Wheeler 1986). In the latter, the community may develop as a floating raft of loose rhizomes over sloppy peat or water and gives rise to the very species-rich *Carex lasiocarpa* variant. Permanently high water levels, low nutrients and little throughput of water may be an important aspect of the hydrology of this vegetation type. It is generally of very high value for conservation and was found frequently in the Ant and also in the Bure. The *Carex lasiocarpa* variant is of particular importance, supporting a wide variety of uncommon species, and is characteristic of the Ant such as at Sutton Fen.

S24b, the *Glyceria maxima* sub-community, is the third community which is close to the pioneer swamp phase of the hydrosere, often developing behind the margin of S5 *Glyceria maxima* swamp. It is characteristic of floodplains with elevated nutrients, particularly the Yare. This was the least frequently recorded sub-community of them all, perhaps reflecting the general decline of *Glyceria* vegetation discussed above.

The Typical sub-community (S24d) can occur either as an early hydrosere fen type, invading most commonly a *Phragmites australis* reed swamp precursor. Where fen waters are lower in nutrients, it may succeed *Cladium* swamp. The sub-community can also be found on firmer, older peat surfaces. Its rather broad environmental amplitude is perhaps reflected in its flora being the least distinctive of all the sub-communities. It was also the second most frequently recorded of the seven reference NVC types.

The S24f *Schoenus nigricans* sub-community is generally found away from the broad margins and pioneer swamp communities, in fen compartments where water tables may be a little lower and winter flooding less. They are characteristic of the uncut fen surface rather than turf ponds (Giller and Wheeler 1986). Wetter examples of S24f have a greater compliment of uncommon mire species and bryophytes, especially where the waters and substrate are particularly infertile. Drier examples of S24f generally have a reduced swamp element and a greater representation of species such as *Calamagrostis canescens*, *Juncus subnodulosus* and *Agrostis stolonifera*. Rodwell (1995) emphasises that S24f, unlike the foregoing sub-communities which can persist at least for a time as primary fen

types, only occurs under mowing regimes, and this is usually as commercial sedge beds (Giller and Wheeler 1986). Stands of this sub-community were quite frequent (175 samples were referred to it), and it was the only sub-community of S24 with a significant presence in the Thurne catchment.

S24g, the *Myrica gale* sub-community, appears to be associated with lower water tables than the foregoing. It is also associated with cessation of mowing, particularly of *Cladium* beds and may succeed S24f in such circumstances (Giller and Wheeler 1986). The increasing density of vegetation and fierce competitive prowess of *Cladium* may explain why this is the least diverse of all the S24 sub-communities recognised by the NVC. Regular cutting is important in controlling the scrub growth habit of *Myrica* and its frequent companion, *Salix repens*. In later successional stages, the community can resemble a dense scrub habitat, especially if other tree saplings start to ingress, although this was rarely the case in the current survey. More samples (331) were attributed to this sub-community than any other.

The driest sites of all appear to be associated with S24c, the *Symphytum* sub-community. This is not a Broadland speciality, being the type community on Fenland sites such as Wicken and Woodwalton fens, and in fact in the current survey only an intermediate with the *Glyceria maxima* sub-community was recorded.

A new mixed mire community has been proposed, the BS5 *Dryopteris cristata*-*Sphagnum* species fen. This has close affinity with S24, having nearly all of the characteristic associates Rodwell uses to define this community. However, the poor-fen ground layer and, in particular, the rich community of *Sphagnum* species, suggests it cannot be accommodated in this essentially calcareous tall herb fen community of S24. It has therefore been given its own. It is a rare community in Broadland, with only 57 samples ascribed to it, and has not been described nationally – Wheeler's *Betulo-Dryopteridetum cristatae* (Wheeler 1980c) which refers to this vegetation type, is also restricted to the Broadlands. The community occurs within fen compartments, not at the valley margins. It can be very small in extent (Wheeler 1978 indicates stands can be as little as 1-2m across) and is consequently easily overlooked. Giller and Wheeler (1988) regard this as a primary fen type, not recorded in regularly mown stands, perhaps explaining the tendency of the community to include a component of birch scrub.

In this vegetation, a quite different hydrology has led to the development of a "mixed mire" flora. Deep rooted species in the community are typical of the base-rich and calcareous flora of S24, although they are much reduced in frequency and abundance. Shallow rooted species and the bryophyte flora are mostly poor-fen species. This suggests there is a perched, very shallow, surface water table which is maintained just above the base-rich water table, even when the surrounding rich-fen community may be inundated. In some locations (such as "the heater" at Barton Broad) the hydrological equilibrium may be maintained by the floating nature of the substrate. The peat body rises and falls as the broad water level changes, maintaining a constant vertical relationship between base rich and base poor layers. Giller and Wheeler (1988) suggest that the floating rhizome mat in old peat cuttings operates in the same way, while on solid peat the shrinking and expansion of the peat body performs the same function. They suggest that in extensive areas of what appear to be similar floating or solid substrate, small differences in rhizome mat buoyancy or peat absorptive capacity may be enough to provide the required isolation of the surface in the very small areas that the vegetation occupies. They found no

difference in the chemical properties of the peat - *Sphagnum* did not develop over specifically acidic peats. The ability of the peat surface to rise above the base-rich water table thus provided suitable conditions for the ingress of the first *Sphagnum* species. The ability of bog moss to retain base-poor rainwater within its tissue, and to acidify the surrounding surface, subsequently increased the potential for acid fen development.

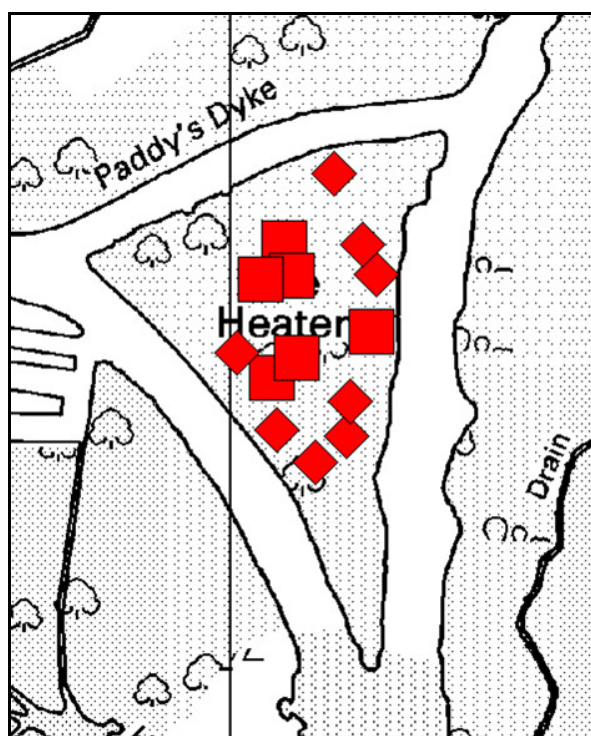
In support of the buoyant surface theory, Giller and Wheeler (1988) cite the fact that this acid community principally develops over *Typha-Phragmites* rafts, which can have buoyant rhizome rafts, but not over former *Cladium* communities which have rhizomes rooted into solid ground and tend to be flooded by the base-rich water.

The successional development of this community is not clear. Being primary fen, readily invaded by trees, stands of this vegetation would, if left unmanaged, progress rapidly to trees. Giller and Wheeler (1988) indicate the *Sphagnum* carpet would persist under the canopy, as might an impoverished version of the flora²³, and they assert that there is evidence of long term of die-back of the tree canopy. Consequently, they speculate that these acid nodes within rich-fen represent the beginnings of ombrotrophic bog development. Bog formation from *Sphagnum*-rich vegetation on raised topography within the fen was also proposed by Pallis (1911), although she felt carr woodland was a more likely outcome than raised bog.

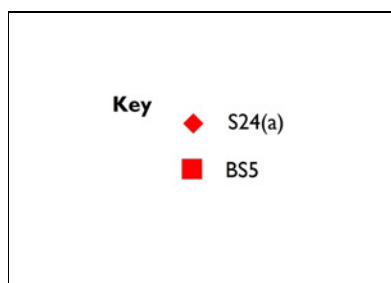
One of the best illustrations of this formation is The Heater, on Barton Broad (Figure 8). Here the *Dryopteris-Sphagnum* vegetation occupies the centre of the compartment and is ringed by rich-fen, in this case the *Carex paniculata* sub-community of S24. In places, especially near the broad margin, the S24a is extremely wet and treacherous to walk on. Field experience suggests the central peat mass is significantly higher than the S24 fen around, raised almost dome-like. Topographic levelling would be required to confirm the shape of the compartment, but there is a clear sense in the field of the early stages of a raised mire.

²³ The community may therefore succeed to the *Sphagnum* sub-community of W2 *Salix cinerea-Betula pubescens-Phragmites australis* woodland, where Rodwell (1991a) originally placed all of this vegetation – see *Results* section of this report.

Figure 8: The Heater, Barton Broad.



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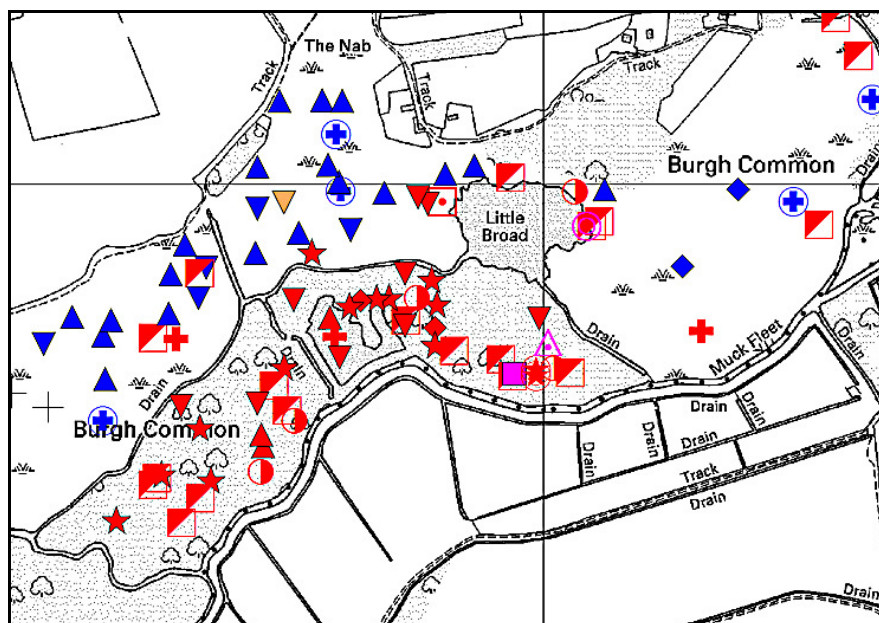
One very important plant community not recognised in the current survey is the *Peucedano-Phragmitetum caricetosum*, which Wheeler placed with the other S24 sub-communities but was placed in M9 by Rodwell (1991b). This vegetation type was one of the most important and species-rich, unique to Broadland, supporting a wide range of rare species including *Liparis loeselii*. Characterised by a diverse range of small sedges and a flora typical of very wet fens, it grew in old turbaries close to the floodplain margin with calcareous, base-rich and low nutrient substrates, (Giller and Wheeler 1986) and was often managed for sedge. The sites were characterised by very stable water levels, assisted by the loose mat of vegetation which behaved much like hover. Although rare it could be extensive, such as the 2-3 acre stand described by Wheeler (1978) from either Catfield or Sutton Broad Fen. Identification of this vegetation type is not helped by the absence of detailed floristic profiles in Wheeler (1980a, 1978), and Wheeler's own observation that the community is variable and without particular species that characterise it well (Wheeler 1978). Review of the samples from this survey, using the more detailed textual descriptions he made still did not really reveal any examples. The

absence of this vegetation type could be attributed to the much smaller sample size used in this survey, and/or to environmental change. Wheeler's samples on which this community is based were recorded 30-35 years ago. Even in the late seventies, Wheeler (1978) cited on-going terrestrialisation of old peat workings as a cause of change to the substratum and the floristics of this vegetation. He refers to *Peucedano-Phragmitetum caricetosum* as "...almost certainly a community declining in extent". He records that the location of a former colony of *Liparis loeselii* at Broad Fen Dilham is now a very dry form of *P.-P. caricetosum*. This has probably progressed to either M13c, S24e or S24f, all of which form a mosaic in the southern part of the site (see Figure 2). A similar site on Sutton Broad Fen he described even then as overgrown and impoverished. Again, this site is now a mosaic of S24 communities (Figure 7) with frequent stands of S24e which include the *Carex lasiocarpa* variant which is closely related to *Peucedano-Phragmitetum caricetosum*.

The *P.-P. caricetosum* is described as "short-lived", by Giller and Wheeler (1986), succeeding to other S24 communities typical of the uncut peat surface, eventually to the *Schoenus nigricans* sub-community. Significantly, they suggest this succession will take place even if the community is cropped due to the accumulation of peat by rhizome growth. Peat infill causes progressive convergence of the hydro-chemical properties of the turf ponds and the uncut peat surfaces, with accompanying convergence of vegetation. Re-excavation of shallow turf ponds appears to be the only long term strategy for maintaining this community, although the life-span of turf ponds generally, and of this vegetation type specifically, is not known. Wheeler and Giller (1986) quote rates of peat accumulation of around 1.5cm/year. This gives a 70cm turf pond a life of around 50 years, but this must be an underestimate as cartographic evidence they quote suggest their study sites were 100-140 years old. The species-rich successional phase is likely to be only a segment of this, but this period of stability is no better understood for this than any other fen type.

The value of turf ponding in modern times is illustrated by Burgh Common. Southern parts of this isolated fen area had become heavily scrubbed up. The Broads Authority undertook restoration of the area with in-house machinery, creating turf ponds. Figure 9 shows the plant communities which include high quality S24 wet fen. Figure 10 shows the distribution of RWPFSS scores on the site. The turf pond scores very highly, placing the site alongside the best sites of the Bure and Ant. Similarly, the M13 *Schoenus-juncus* fen at Broad Fen, Dilham, was located in recently excavated shallow turf ponds (Figure 2) as was much of the best S24 vegetation. The co-incidence of high quality wet fen with recent turf ponding was noted in many sites in the Ant and Bure catchments. The evidence in support of turf ponding for conservation is compelling.

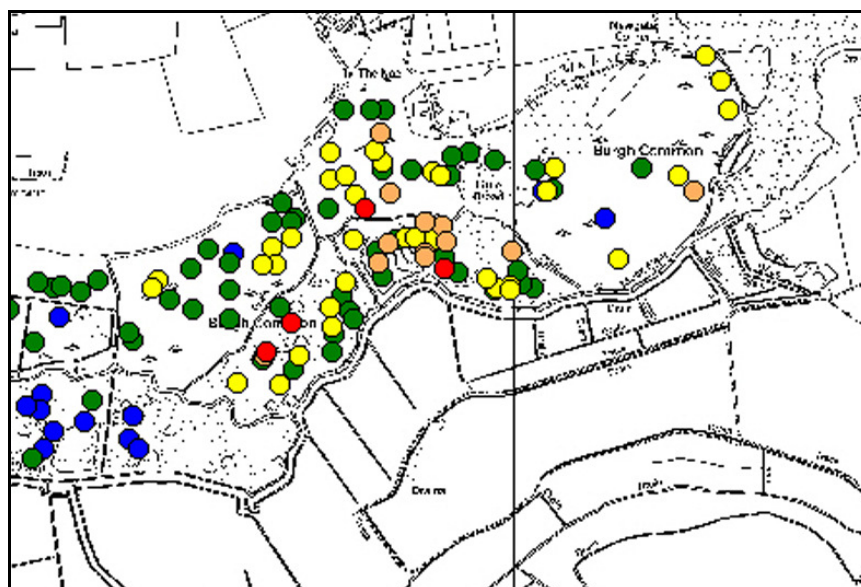
Figure 9. Plant Communities in the Turf Ponds at Burgh Common. The area south of the drain was formerly wooded but then cleared and turf ponds excavated. The vegetation consists of a range of S24 sub-communities.



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Key			
◆	S24(a)	+	S24(f)
▲	S24(b)-(c)	◻	S24(g)
▼	S24(d)	◻	S24-S25
★	S24(e)		

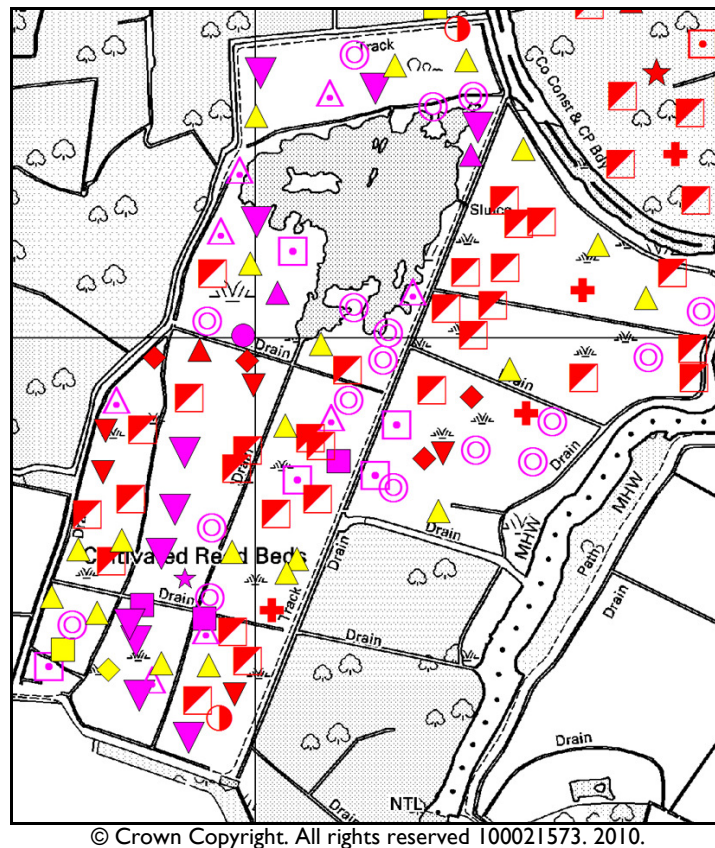
Figure 10: RWPFS at Burgh Common. Note the preponderance of orange and red scores in the turf ponds (cf. Figure 9). Red = 8.0 or more, orange = 6-8, yellow 4-6, green 2-4, blue 0-2



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Although substrate and hydrology may determine the gross division and floristics of S24 sub-communities, management treatment can strongly influence the composition within sub-communities and in particular the degree of dominance by certain species, especially those with a crop value. Where the influence of management treatment is particularly strong, and especially where it is combined with artificial manipulation of environmental factors, shifts to other communities can occur. For instance, managing a stand of S24 largely dominated by reed through winter mowing could shift the whole community to species-poor S4 *Phragmites australis* swamp, especially where mowing is combined with raising water levels. Management for a crop such as reed may deplete the associated flora, hence commercial reed harvesting is considered detrimental to botanical conservation. However, many stands mown for reed in this survey still recorded high botanical value. Commercial reed beds on the Ranworth Flood, for instance, supports a diverse range of fen types (Figure 11), many of which are of value for conservation such as S24 a, c, d and f, and S27b. All stands are strongly dominated by reed but the area still supports a significant fen flora. There is a proposal to raise summer water levels on the site to further enhance the density of the reed (Rick Southwood, pers. comm.), but this is likely to push the communities much closer to S4 *Phragmites* swamp, a detrimental change. A full assessment of the floristic resource of commercially managed reedbeds would be possible using data from this survey.

Figure 11. Fen Communities at The Ranworth Flood.



Key		
◆ S24(a)	◻ S4(a)	
▲ S24(b) - S24(c)	△ S4(a) Lemna spp. variant	
▼ S24(d)	⊙ S4(b)	● BS1
✚ S24(f)	■ BS3	▼ S4 BS(g)
◩ S24 - S25	▲ S4 BS(f)	▲ S27(b)

Clearly, understanding the nature of any existing stand of S24 depends on knowledge of both the environmental factors operating on the vegetation, and its history of management. It is difficult enough to obtain precise information on a site's hydrology and hydrochemistry, but obtaining long term management history may be impossible. As Lambert (1951) suggests, the frequency with which a stand is mown is likely to depend on the demand for the main product, available labour, weather, landowner decisions and probably a host of other factors. The detailed history of management for individual compartments has not been compiled in Broadland, as far as we know. The opportunity

to obtain reliable historic management information has probably gone. Making further progress in understanding the precise relationship between management and environmental factors on S24 vegetation probably now requires an experimental approach. While this applies to most Broadland vegetation types, the issue is especially important for S24 because of its particular floristic complexity, its great extent and its high conservation value.

Other Oligo-Mesotrophic Tall Herb Fens

The loss of many of the key S24 associate fen species marks the transition to a more species-poor tall herb fen, S25 *Phragmites australis-Eupatorium cannabinum* fen. There are substantial numbers of samples of this community, plus 1025 samples of a vegetation type which is intermediate between this and S24. Rodwell (1995) indicates that S25 fen is associated with "...a moderate level of nutrient enrichment", often maintained through regular inundation of fluvial water. S25a, the *Phragmites australis* sub-community, recorded in small numbers of samples in this survey, is particularly associated with these conditions. The *Cladium* sub-community was recorded more extensively. It is associated with lower nutrient fens, and includes a variety of commercially managed sedge beds. Rodwell (1995) suggests that S25 is a primary fen community not generally maintained by mowing. His evidence for this appears to be the presence of unmown stands of the vegetation adjacent to cropped stands of M13, M22 and M24. However, it is unlikely that S25 would persist without management, and like all fen types would progress to scrub without intervention.

The historic status of S25 in the Broads is not known but is of considerable interest. The relative restriction of S24 to the Bure and Ant has been referred to above. If the very large numbers of samples of S25, and particularly intermediate S24-S25, are a recent phenomenon it might suggest a shift from S24 to S25, consequent upon an increase in nutrients or reduction in management, or both. There is no direct evidence to support this suggestion, but would be a potentially significant trend with major consequences for the fen resource.

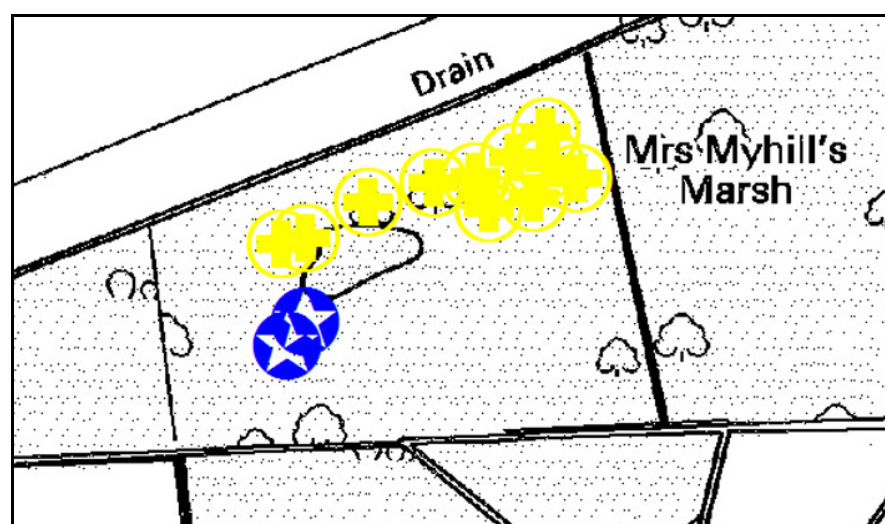
There are two new communities proposed in this survey that are dominated by *Calamagrostis canescens* and quite closely related to S24. The first is BS4 *Calamagrostis canescens* fen, which is very strongly dominated by this species, and very species-poor. With only eight samples recorded, it is a rare community and was restricted in extent at all locations. The second, BS3 *Phragmites australis-Calamagrostis canescens* fen is a much more frequent vegetation type with 154 samples mainly in the Thurne, Bure and Ant valleys. This species-poor community is characterised by dominance of the two species and by non-fen plants or those of more eutrophic or disturbed conditions. A typical location for the community is around the dyke margins of fen compartments, where ditch dredgings have been deposited.

The remaining fen community in the mesotrophic group is S27 *Potentilla palustris-Carex rostrata* fen. The main sub-community is the *Lysimachia vulgaris* vegetation which is reasonably widespread (with 72 samples) although mostly in relatively small stands among other fen communities. This vegetation type is characteristic of high water tables, close to the surface, but without regular or prolonged inundation, and where there is some throughput of water. Samples in the survey had a mean of 54% open water. The *Lysimachia* sub-community has an eastern distribution and is the expected sub-community in the Broads. It is not especially species-rich (14.4 species per sample) but is a

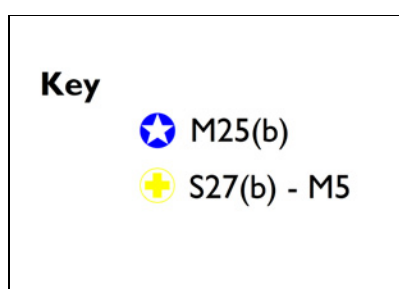
distinctive and uncommon vegetation type in East Anglia, often including uncommon species.

There is a version of this community which has developed on the margins of Mrs Myhill's Marsh, Hickling, in the Thurne catchment (Figure 12). It is intermediate between S27 and M5 *Carex rostrata-Sphagnum squarrosum* mire. Wheeler (1978) refers to this as a valley fen situation, and suggests it has links to similar soligenous acid mire vegetation he recorded at East Ruston but was subsequently damaged by drainage and burning²⁴. The Hickling community is the second mixed mire community recorded in this survey. In addition to the relatively base-rich tall herb fen flora (attributable to S27), the ground layer and short herb flora is indicative of acid mires (attributable to M5). The latter includes an impressive range of *Sphagna* and perhaps most distinctively, constant and sometimes abundant *Carex curta*. The particular hydrological conditions which maintain this poor fen have not been as well documented as those associated with *Dryopteris cristata-Sphagnum* fen, but may be more closely associated with shallow marginal sands and flushing of acid groundwater, rather than swelling or floating peats.

Figure 12: S27-M5 “mixed mire” at Mrs Myhill’s Marsh, Hickling.



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Historically, this kind of vegetation may have been more widespread on valley margins flushed by base-poor ground water, derived from superficial sands. Pallis (1911) refers to

²⁴ Wheeler's vegetation type is no longer present at East Ruston.

what she terms “moor vegetation” (which appears to be a Sphagnacious wet heath) along the “highland margin” of the river valleys, although how common this vegetation was when Pallis was writing is not known. It is one of the valley margin transition communities which has been lost from nearly all of the Broads rivers.

Eutrophic Fens

Perhaps one of the surprises of this survey was the diversity and quantity of tall herb fens typically associated with eutrophic conditions. Whether this represents a genuine expansion of this vegetation type or whether this kind of fen has been poorly considered by previous workers is not currently known. Vegetation of this kind is not discussed by Pallis (1911) or in the work of Lambert, even in the Yare. A significant area of eutrophic vegetation was recorded by Parmenter (1995) although direct correlation is very difficult because of her unique scheme of classification. Although it appears to be a species-poor, unattractive and at times physically painful assemblage, it is diverse in the number of vegetation types it incorporates and in its physical structure. It also supports some uncommon plants, most notably *Urtica dioica galeopsifolia*, recently downgraded to sub-species in Stace (2010).

The core vegetation of eutrophic fen is the S26 *Phragmites australis-Urtica dioica* community. All three of the expected sub-communities were recorded²⁵, plus a new variant of one and three newly proposed sub-communities. S26 is generally considered a primary fen community (Rodwell 1995) historically not mown and having little commercial value. It is typical of a wide range of wetlands whose common environmental characteristic is high fertility, either arising from a nutrient enriched substrate or from irrigation by eutrophic water, or of course both. The community is also often associated with disturbance of the fen surface, and includes a number of indicative species such as *Cirsium arvense* and *Galium aparine*.

In addition to the three reference NVC sub-communities, this survey has proposed three new sub-communities of S26. The first is the S26 BSe *Calamagrostis canescens* vegetation type, with abundant and often co-dominant *Calamagrostis* and a few associate species which characterise S24 fen. It is therefore a bridge between S26 and S24²⁶. It is tempting to conclude this new sub-community is the result of degradation of S24 by eutrophication, drying and/or disturbance but there is no direct evidence of this.

The second new sub-community is the S26 BSf *Carex* species vegetation, where mixtures of *Carex paniculata*, *C. riparia* and *C. acutiformis* are abundant and often co-dominant. Placing this vegetation within the range of fen types described elsewhere is problematic. It may be a more eutrophic form of S24a, the *Carex paniculata* sub-community, or it may be derived from one of the vegetation types rich in pond sedges, these being a meso-eutrophic vegetation type. This new sub-community is the richest of all of the eutrophic fen types.

²⁵ The fourth, S26c *Oenanthe crocata* sub-community, is an oceanic-west community not likely to be recorded in Broadland.

²⁶ Arguably, S26d *Epilobium hirsutum* sub-community, with frequent and sometimes dominant *Glyceria maxima* also shows some affinity to S24, but the range of species characteristic of the latter community is very restricted in S26d.

The third new sub-community of S26 is a BSg Species-poor sub-community, defined by extreme impoverishment (with a mean species-number per quadrat of 4.5), with only reed and *Urtica* being constant. It is a large data set (120 samples) and widespread. The floristics suggest affinity with S4 *Phragmites australis* swamp. The derivation of this vegetation type is ambiguous. It could arise from eutrophication of S4 or from re-wetting of stands of S26.

There is large body of samples which has been classified as OV26 *Epilobium hirsutum* community²⁷. This appears to be characteristic of slightly drier situations than S26, especially in summer (Rodwell 2000). The samples in this survey were variable in their patterns of abundance with *Phragmites*, *Glyceria* or *Phalaris* being the principal dominants, usually alone and rarely co-dominating. This vegetation type, mostly from the Yare, was largely unmanaged which may account for the unusual abundance of both pond sedges. Comments regarding origins of this vegetation would be similar to those made for S26.

The final eutrophic fen community is S28 *Phalaris arundinacea* fen, almost all of which was the *Epilobium hirsutum-Urtica dioica* sub-community. It was an uncommon community, mostly from the Yare, and the frequency of reed and *Urtica* suggests some transition to S26. Rodwell (1995) suggests it marks the normal limit of water level fluctuations, and does not tolerate summer flooding. It also tends to be in less fertile situations than S26 and OV26.

Expansion of S26 and OV26 vegetation types could be promoted by several environmental factors. These include elevated nutrients in river water, the “natural” eutrophication of the fen by lack of management and consequent recycling of fen plant nutrients where they do not enter peat storage (the most likely situation on summer-dry sites), drying and disturbance of the peat surfaces through drainage or agricultural “improvement”, or the deposition of silt associated with dredging of the waterways. A detailed understanding of the mechanisms which determine such change is not available. Processes which reduce eutrophic fen in favour of other vegetation types are largely the reverse – introduction of intensive cropping, direct nutrient stripping measures on the fen surface or replacement of eutrophic river water with low nutrient sources. As the former group of processes appears to be ascendant, certainly for much of the last 80 years, it is likely that eutrophic vegetation is indeed expanding. Nationally, Firbank et al (2000) found that one of the two major trends in British vegetation was from less fertile to more fertile vegetation. In the Broads, the eutrophication of river and Broads waters is well documented and nutrient reduction strategies have been put in place (Moss 2001). When reviewing time series of vegetation data (including from this survey) in Broadland, ELP (2010a) recorded an increase in species of high nutrient conditions at three of the five sites examined. Across all sites, vegetation appeared to have become taller and reed increased, although the latter two may be related to management. Together, this evidence indicates that the trend toward eutrophic vegetation suggested by this survey is genuine, but such evidence remains circumstantial and direct evidence is more difficult to obtain.

Less clear is whether this trend is affecting all of the valleys at the same time or to the same degree. The centre for this vegetation type is the Yare, which has always supported

²⁷ Of the 149 samples attributed to this community, 139 are from the *Phragmites australis-Iris pseudacorus* sub-community. This is the only true fen vegetation type in this NVC community. Its placement here rather than in the main tall herb section is anachronistic.

communities at the meso- to eutrophic end of the fertility spectrum (George 1992, Lambert 1946), but Lambert does not include vegetation types which are comparable with S26 or OV26 in her accounts. There are also many samples in the current survey recorded from the Bure, which has not previously recorded significant amounts of this vegetation type. The vegetation is still relatively rare in the Ant and Thurne. Whether eutrophication and dereliction processes are less prevalent in these catchments, or whether they are buffered by more favourable water chemistry to start with (particularly high calcium and salinity levels respectively) is not known.

4.4 Saltmarshes

The majority of vegetation types showing mild saline influence are described in swamps and tall herb fens, section 4.3. None of the mires and fen meadows (section 4.2) are strongly influenced by brackish waters, mostly because they are located on valley margins, in valley fens, the upper reaches of the main rivers or in catchments with minimal saline influence such as the Ant.

Saline influence in the Broads is concentrated in two main geographical areas. The first is the Thurne catchment, particularly areas east of the Hickling-Martham Broad line, due to its proximity to the sea. Here, the coastal saline aquifer is naturally close to the ground surface, but has been drawn further inland through drainage and pumping of the coastal sub-catchments such as Somerton and Brograve (Harding and Smith 2002). The pumps discharge salinised groundwater which is further distributed through the system by flows in the broads and rivers. Moss (2001) states that around 1900, the chloride concentration in Hickling was around 600mg/l, whereas a hundred years later it was 2000 mg/l. Studies on salinisation of the upper Thurne are preliminary (e.g. Harding and Smith 2002), but is an area of concerted research effort by the University of Cranfield. Although true saltmarsh communities have been recorded in the Thurne, samples are very few as it does not receive the regular saline intrusions characteristic of the lower Yare and Waveney. Consequently, salinity is mostly expressed in the swamp and tall herb fens described above, showing rather mild brackish influence.

The second main area which is subjected to brackish influence is the reed rond habitat, which lies between the river embankments along the lower courses of the Waveney, Yare and to a lesser extent the Bure. All three rivers, but particularly the Yare and Waveney, are subject to salt tides passing upstream from their estuary discharge points. These have increased in terms of frequency, duration and upstream penetration. George (1992) cites a variety of reasons for this, the major ones being the removal of downstream pinch-points which restricted upstream flow, and an increase in channel capacity through dredging. As with a conventional saltmarsh, elevation across the rond toe and up the embankment determines the frequency and duration of inundation and therefore the compliment of saltmarsh species. If inundations are increasing, so should the extent of the saltmarsh flora, climbing up the elevations of the river ronds and following salt incursions further inland. George (1992) indicates this process has been continuing for at least 100 years. Winter storm saltwater surges are particularly severe, if short-lived – George (1992) recounts that in February 1988, a surge filled an off-river mooring basin, resulting in water which was 65-75% seawater and killing around 100,000 fish. The Yare and Waveney have the most severe salt water inundations because they discharge directly to the head of Brayden Water, where tidal surges can funnel directly up their main channels. The Bure has its mouth at 90° to the tidal flow, which means much of surge flows past,

and it is further buffered by a great meander just upstream which restricts the passage of a surge. The Thurne and Ant are quite remote from surge waters.

There is a third, more minor but widespread influence. Mild brackish influence in the vegetation of internal fen compartments of most catchments has been recorded in the survey. It is a relatively minor influence, arising either from seepage of saline river water through the river embankments, or from exposures of underlying marine clay laid down in estuarine conditions during the Romano-British Transgression. Although it does appear to create moderate elevations in brackish conditions for fens, leading to the development of reed communities rich in *Agrostis stolonifera*, this kind of brackishness may be a more significant issue for invertebrates. In the survey of fen invertebrates that was conducted in parallel to this, Lott et al (2010a) found that invertebrates of dykes were impoverished by elevated salinity. Perhaps significantly, invertebrates of the adjacent marsh and fen were not affected, suggesting saline seepage is captured by the dykes and does not penetrate the fen surface, accounting for the relatively mild impacts of seepage on fen vegetation.

The long-term impacts of the great sea inundations of 1938 (when 700 yards of the dunes between Winterton and Horsey were washed away) and 1953 are not known.

The vast majority of samples attributable to the true saltmarshes have been recorded on the river ronds. An example from the lower Yare is shown on Figure 13 below. Although they are communities which are clearly referable to the saltmarsh communities of the NVC, they have a tier of reed over the halophytic flora which is not recorded in the reference NVC types. *Phragmites* communities in an estuary or brackish context are only described in the swamps section of the NVC, particularly S4 *Phragmites australis* swamp, the *Atriplex prostrata* sub-community. The kind of reed with saltmarsh vegetation recorded here has been overlooked in Rodwell (2000), and is not referred to in Rodwell et al (2000). Further sampling in estuaries and tidal rivers may suggest new sub-communities are warranted.

The most saline community with the most frequent inundation recorded in this survey was SM13d *Puccinellia maritima* saltmarsh, the *Plantago maritima*-*Armeria maritima* sub-community. It was recorded from only two samples in the Yare.

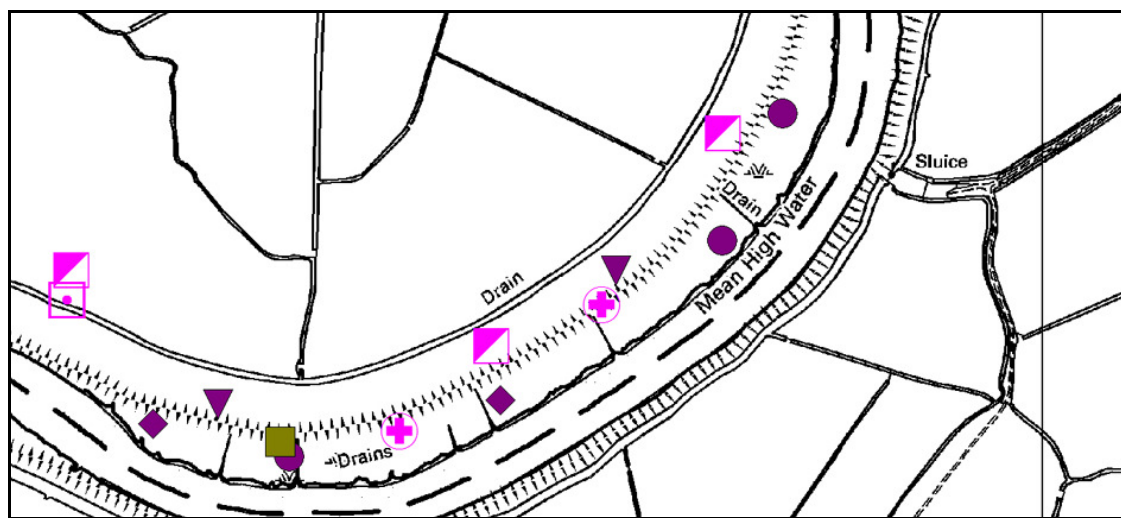
Nearly 87% of the saltmarsh samples were assigned to SM16 *Festuca rubra* vegetation, typical of the mid- to upper-saltmarsh. Three sub-communities were recorded in the current survey. The *Puccinellia maritima* sub-community is associated with the most frequent saline inundation. The reed is thin and very stunted (mean height 15.3cm), and the vegetation was composed almost exclusively of saltmarsh species. Rodwell (2000) records that this sub-community may be subject to more than 250 submergences per year. In the *Juncus gerardii* sub-community, the reed is on average 40.3cm tall. This, together with replacement of *Puccinellia* with *Juncus gerardii*, indicates reduced exposure to saline water. The third SM16 vegetation type is the *Agrostis stolonifera* variant of the *Festuca rubra*-*Glaux maritima* sub-community, where reed is now on average 86.2cm tall. The community includes some freshwater fen species, uniquely among the three SM16 units. This marks a further shift toward freshwater conditions. Rodwell (2000) estimates that the *Festuca*-*Glaux* sub-community as a whole may receive 150-200 submergences per year.

The only examples of SM16 mapped in eastern England by Rodwell (2000) are on the north Norfolk coast, close to the Wash. This appears to be essentially a west of Britain community. Its presence inland and in the Broads is therefore distinctive and of interest.

Three communities of progressively less saline influence were recorded with less than five samples each. In order of decreasing brackishness (Rodwell 2000) they are SM20 *Eleocharis uniglumis* saltmarsh, SM23 *Spergularia marina-Puccinellia distans* saltmarsh and SM24 *Elytrigia atherica* saltmarsh. This trend includes an increasing trend of dryness, too, with the last vegetation type being a relatively rank and dry community of river wall slopes.

The Yare rond illustrated in Figure 13 shows the sequence of communities arranged according to salt water influence. The SM16 saltmarsh sub-communities are positioned on the flat toe of the river wall, adjacent to the Yare channel. On the river face and crest of the wall is SM23 *Spergularia marina-Puccinellia distans* saltmarsh. On the crest but especially flanking the inside soke dyke are *Agrostis stolonifera* variants of S4a and S4b *Phragmites australis* swamps. These have the mildest brackish water influence.

Figure 13. Saltmarsh vegetation on the left bank ronds of the River Yare at Reedham Marshes.



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Key

- ◆ SM16(a)
- SM16(b)
- ▼ SM23
- ◻ S4(a) Sol dulcamara variant
- ⊕ S4(d)-SM24
- S21(a)
- ◻ S4(a) Ag stolonifera variant

It is highly likely that saltmarsh and brackish tall herb fens are increasing in the Broads. The early accounts of Pallis and Lambert make little reference to these communities. By the early 1980's the NVC (Rodwell 1995) had mapped none in the area, and Wheeler (1980a-c) does not incorporate brackish communities into his scheme. It was not until Parmenter's (1995) work that these communities were first described from the Broads in her B46-B53 communities, from the lower Yare and Waveney. However, no hectareage of the NVC equivalents was provided because of insufficient data. Although these observations are corroborated by known changes in the salt surges and catchment salinities as described above, it is emphasised that there is no direct evidence.

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5. CONSERVATION IMPORTANCE OF BROADLAND FEN COMMUNITIES.

5.1 Representation Of EU Habitats Directive Fen Types

The fen features which qualify under the Directive are described on the JNCC website (http://www.jncc.gov.uk/ProtectedSites/SACselection/SAC_habitats.asp). There are four features for which the Broad fens qualify, summarised below.

Maps showing the distribution of these features are presented as large-scale and higher quality maps are provided as JPEGs on the data disk accompanying this report.

7140 Transition Mires and Quaking Bogs

This is essentially a feature which is transitional between acid mires and alkaline fens, ranging from markedly acid to mildly base-rich. The JNCC website lists the following NVC communities present in the Broad fens which qualify under this feature: M5, some kinds of M9 and S27.

In the current data set, S27 and BS5 are the main expressions of this feature, as the single M9 sample is probably more appropriately placed in another SAC feature. The feature would also include the cluster of M9-S27 samples from Mrs Myhill's Marsh.

7230 Alkaline Fens

This is a feature which encompasses short-sedge mires fed by calcareous, low nutrient and base-rich waters. The two NVC communities which are components of the feature and occur in the Broad fens listed by the JNCC are M9 and M13. This is the most likely placement of the single M9 samples and most of the M13 vegetation types. This feature is very restricted in the floodplain fens of the Broad fens.

6410 *Molinia* meadows on calcareous, peaty or clayey-silt laden soils (*Molinia caerulea*)

According to the JNCC web site, this feature is represented by M24 *Molinia caerulea*-*Cirsium dissectum* fen meadow. Stands with much *Cladium* are also included in the following feature. Acid *Molinia* meadows are specifically excluded from the feature by JNCC. In the maps on the data disk, examples of M25 *Molinia caerulea*-*Potentilla erecta* mire have been included because it has a significant calcareous element in the Broadland context. It has also been the local practise to include this community in the feature by local Natural England staff (Rich Southwood, email 09/09/10).

7210 Calcareous fens with *Cladium mariscus* and species of the *Caricion davalliana*

This feature is a priority under the Habitats Directive, being very rare in the UK and Europe. According to JNCC it is only recorded in 13 SACs, the smallest number for any mire or fen feature. Definition of the feature is somewhat obscure, with the following provided by JNCC:

This Annex I type comprises the more species-rich examples of great fen-sedge *Cladium mariscus* fen, particularly those stands enriched with elements of the *Caricion davallianae* (i.e. small-sedge fen with open low-growing sedge vegetation). Such stands occur in the following situations:

1. sites with a mixture of closed, species-poor *Cladium* beds, which at their margins have transitions to species-rich small-sedge mire vegetation;
2. sites where *Cladium* beds retain their species-richness owing to management; and
3. situations where *Cladium* fen is inherently species-rich, possibly owing to the fact that conditions do not allow the *Cladium* to grow vigorously and dominate the vegetation.

Clearly there is very wide scope in the interpretation of this guidance – principally in how much *Cladium* there needs to be and how the first criterion above is to be interpreted. JNCC lists the following NVC communities recorded in this survey: S2, S24, S25, M9, M13 and M24. However, only those stands with “abundant” *Cladium* in the appropriate context should qualify. In addition JNCC stress that the list is not exhaustive – stands of other communities which are floristically close to these but have abundant *Cladium* would qualify. Some samples of M22 or the *Cladium* variant of S4a could therefore be included.

Consequently we have followed the straightforward practise already adopted by Natural England (Rich Southwood, email 09/09/10) of including all samples in the survey that recorded *Cladium* with a Domin value of 5 or more as qualifying for this feature.

5.2 Unique Fen Types

The pre-eminent fen type which is almost entirely restricted to Broadland is the S24 *Phragmites-Peucedanum* tall herb fen. Although there are outliers of the community in Somerset, Cambridgeshire and Yorkshire, these are few in number, fragmentary and modified versions of, in most cases, the *Symphytum officinale* sub-community²⁸. Otherwise, the entire national resource of S24 is in Broadland.

The proposed new community BS5 *Dryopteris cristata-Sphagnum* species fen is especially important for its uniqueness, its rarity even in Broadland (and therefore nationally), its ecologically distinctive character as a “mixed mire”, its inclusion of rare species (most noticeably *Dryopteris cristata* which occurs only very rarely in other communities) and its hydrological fragility. It is also significant in that, uniquely, it may mark the onset of raised bog formation. This community naturally occurs in scattered, small fragments and is very susceptible to scrub encroachment. The conservation of this vegetation type would seem a particular priority.

A second community of particular conservation importance is the *Peucedano-Phragmitetum caricetosum* (Wheeler 1980a, discussed above). It is a well documented community and of great conservation interest for its diversity and as a habitat for a number of rare Broadland fen species. Like BS5, it is unique to Broadland. The shallow, calcareous and low-nutrient turf pond habitat, and it's very precise location on the turf pond succession, conspire to severely restrict the extent, distribution and life span of this vegetation type.

²⁸ Pure forms of the *Symphytum* sub-community were not recorded in the Broads during this survey, only a version which was intermediate with the *Glyceria* sub-community.

P.-P. caricetosum was not recorded during the current survey. Reasons for this are discussed in more detail elsewhere, but include successional change as a probable main cause. It should not therefore be overlooked in the canon of Broadland vegetation types. Its current status, distribution and conservation needs should be investigated further.

A range of other new communities, sub-communities and variants were proposed in this survey (see Table 1 for a list). They have not been previously recognised in the literature and could therefore be considered unique, at least until further sampling and analysis from elsewhere confirms their status. Some, such as the new sub-communities of S4, are of botanical and conservation interest for the range and rare species they support. Some, such as the eutrophic fens and the new sub-communities of S26, are not of significant botanical interest.

What is almost certainly unique to Broadland, however, is the great diversity of vegetation types present in one area of wetland. This attribute relates particularly to base-rich tall herb fens. While other parts of the UK have more extensive areas of mires, especially in the uplands, these are generally acid in nature, with the exception of fens on limestone which are generally small in extent by comparison with Broadland. Few places have the range and quality of swamps and tall herb fens that the Broads can boast today, despite the changes described elsewhere.

5.3 Extent and Ecological Context

The Broadland fens constitute 1750 ha of semi-natural vegetation. There are few areas of the UK which offer a similar area of fen, particular tall herb fens. Figure 14 shows the area of each of the main fen communities. A detailed breakdown of the area of all of the vegetation types included in the survey can be found in Table 1 of the *Results* section.

The most extensive communities are S4 *Phragmites australis* swamp at 332.7 ha (19% of the fen area) and S24 *Phragmites-Peucedanum* fen at 306 ha (18%). The intermediate between S24 and S25 *Phragmites-Eupatorium* fen is also a major vegetation type at 255.2 ha (14.6%). Perhaps surprising is the area of eutrophic fen, with the core communities of S26 and OV26 together comprising 232.8 ha or 13.3% of the Broadland fen resource. The total area of fen meadow and mire vegetation is significant at 138.3 ha (8%), although nearly three quarters of this is M22. Comparative data are difficult to come by, but the Broads may hold the most extensive tracts of these particular community types in the UK. The figure under-represents certain vegetation types such as *Cladium* and pond sedge vegetation. Because of the nature of NVC communities, stands rich in both can be represented in a variety of vegetation types spread across Figure 14.

There may have been significant changes in the extent of some of the most important fen vegetation types as discussed above. It is difficult to quantify change in extent as there are few comparable surveys from previous time periods. Parmenter (1995) calculated an area of 477.67 ha of S24, around 58% more than the current survey. She recorded a similar amount of S25 to the current survey, but less than 5ha of the much poorer S24-S25 intermediate. It is possible that there has been a shift from S24 to S24-S25 intermediate in the 20 years between surveys, but it is difficult to be certain.

Figure 14. Areas of the Main Vegetation Community Types. Data aggregated from that shown in Table I in the *Results* section.

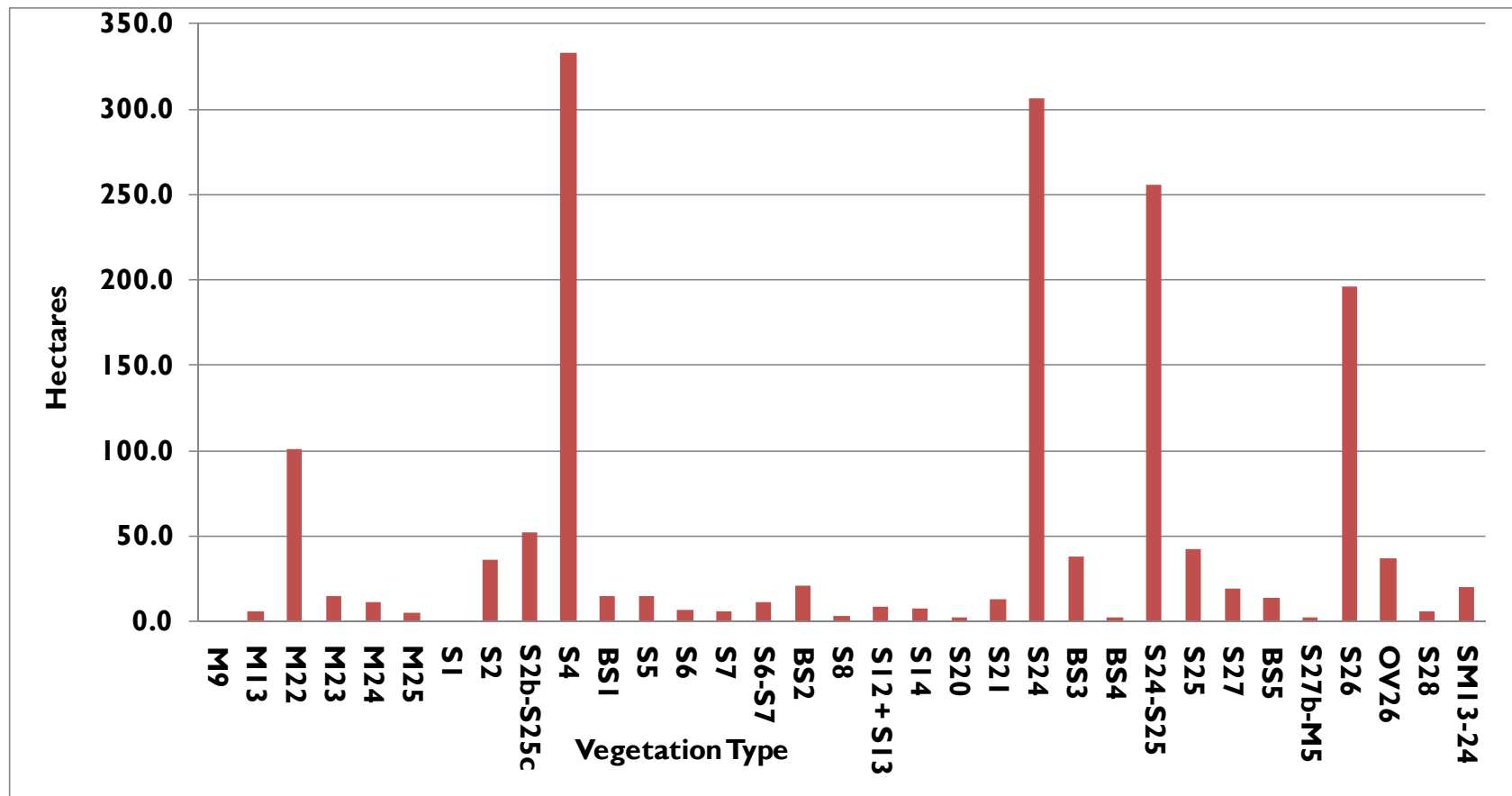
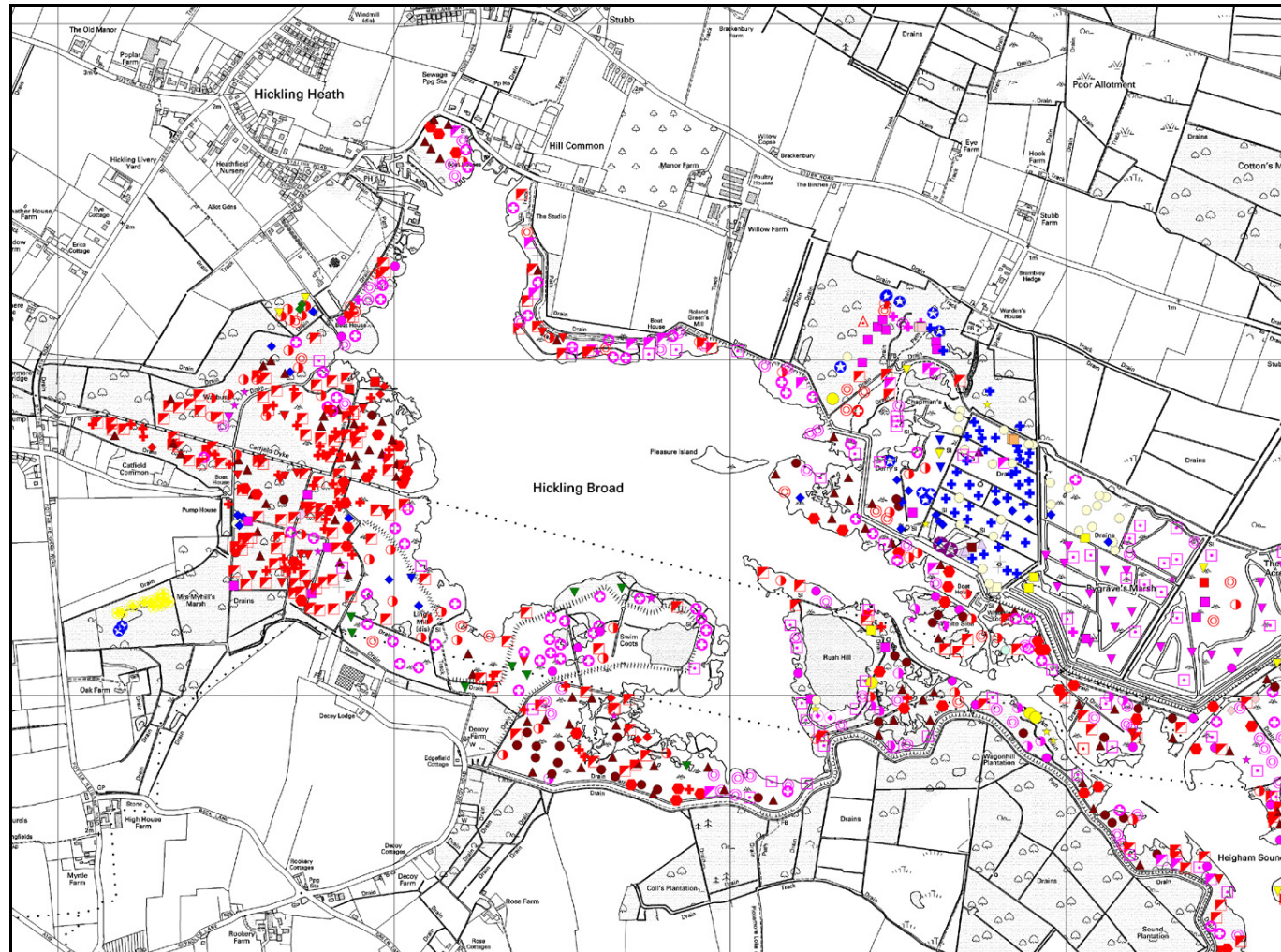
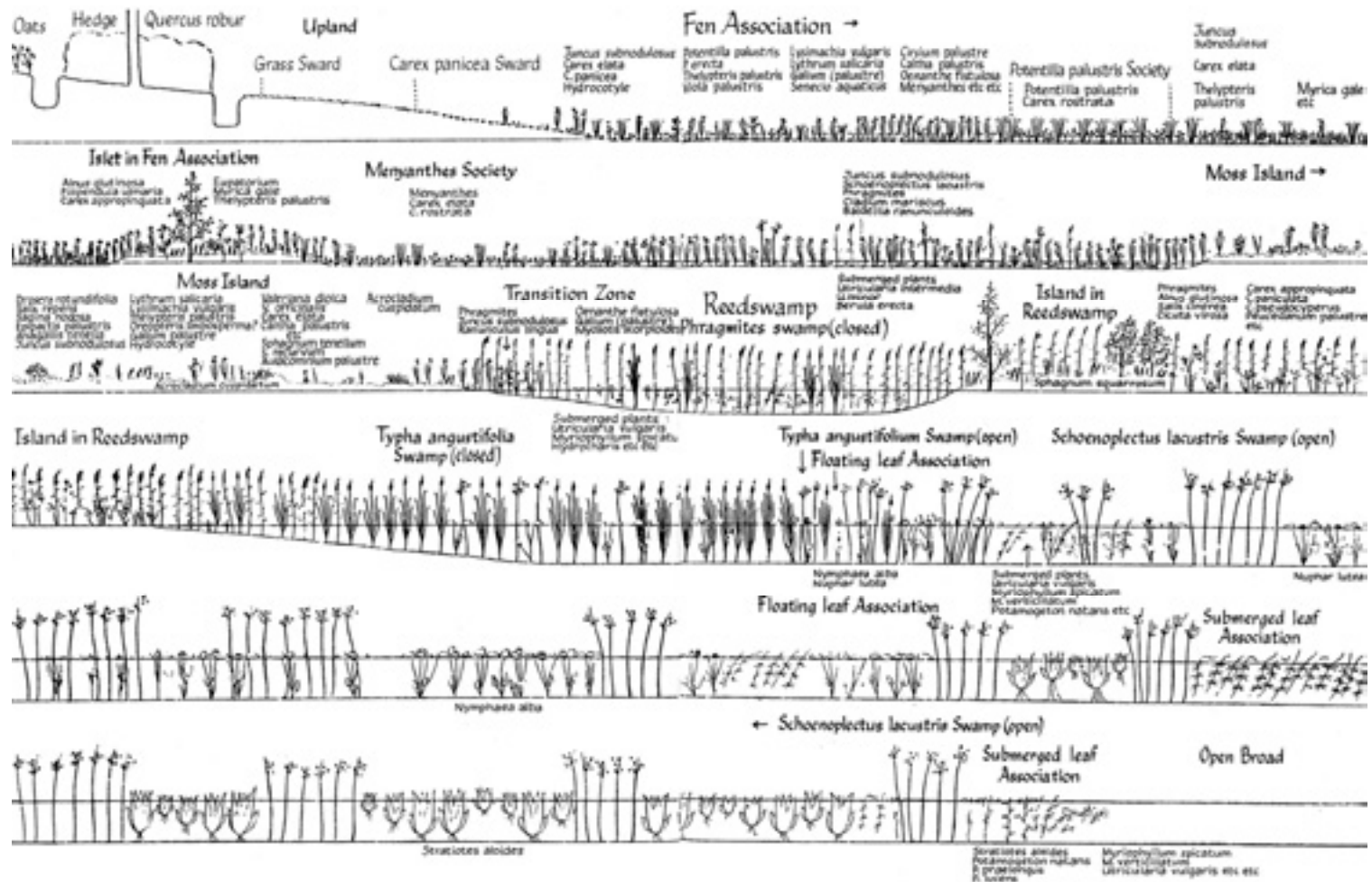


Figure 16: Vegetation Patterns around Hickling Broad. The arrangement of communities is again largely a patchwork rather than seral.



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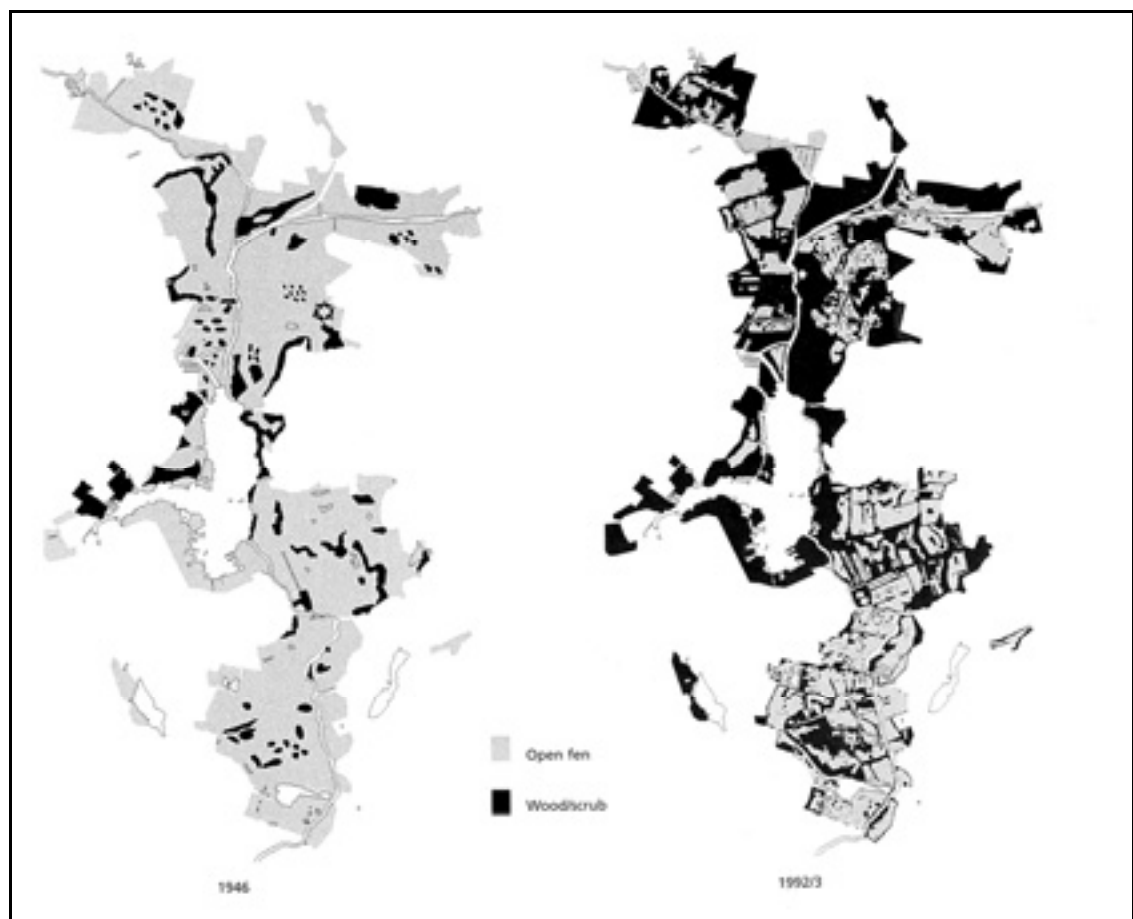
Figure 17. The Classic Hydrosere Described by Pallis (1911) to the west of Barton Broad. Redrawn with updated plant names by George (1992).



Historically, the vegetation of Broadland has been understood in terms of the hydrosere. The classic hydrosere around Barton Broad is shown in Figure 17. Lambert (1965) summarises the vegetation of the Broads as follows “....it is often possible to see the whole range of communities belonging to one series, neatly arranged in concentric zones....”. Good examples of complete hydroseres as described by Lambert are now impossible to find.

The reasons for the loss of the aquatic macrophyte and pioneer swamps of the early hydrosere include impact of coypu, water quality changes, scrub and woodland growth, and increased intensity of recreational use of the Broads and its margins. The opposite end of the hydrosere, the dryland transition, has been truncated by drainage, agricultural improvement and scrub overgrowth. The importance of scrub woodland in truncating the hydrosere is shown in Figure 18, where the managed floodplain is now squeezed between scrub margins advancing from the broad edge and highland margin. The conflated impact of these various types of change means that early and late hydrosereal stages exist now only in disjointed fragments or in very compressed and degraded strips.

Figure 18: Development of Scrub around Barton Broad. From Tolhurst (1997).



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The portion that has survived better than any is the mid-stage hydrosere occupying the internal fen compartments. Here, a wide range of seral vegetation types continue to exist, the particular successional stage of a stand of vegetation being determined by the age of the peat surface and the management they receive. The mid-floodplain fen communities may always have been patchy in their disposition. Certainly, Pallis's (1911) transect in the Ant catchment shows a rather disrupted hydrosere in the middle stages (Figure 17), with shallow peat cuttings and raised "moss islands" interspersed among the fen meadows and tall herb fens of the floodplain level. If the transect was mapped onto a two-dimensional planform view, these middle sections of the hydrosere would almost certainly resolve into mosaics determined by micro-topographical and hydrochemical variation.

Although these patchworks of vegetation types may have persisted to the present day, they are likely to have been modified in the last hundred years. Lack of management and eutrophication in some parts of the Broads has almost certainly coarsened the grain of the mosaic, but the degree of change is difficult to define.

5.4.2 Species and Structural Diversity

Species Diversity

This section considers species-richness of the fen communities, and the distribution of stands of species-rich vegetation in the Broads, using the Rarity Weighted Principle Fen Species Score (Wheeler 1988) calculated for each sample and each community. The frequency distribution of RWPFS is as follows:

RWPFS	% in data set	No. samples	Colour on maps
8.01 or above	0.68	48	red
6.01-8.0	1.93	136	orange
4.01-6.0	11.72	825	yellow
2.01-6.0	33.25	2340	green
0-2.0	52.42	3689	blue

Clearly, fen samples with high scores are rare, with most samples scoring less than 2. However, this index should not be interpreted blindly. Habitats that are by their nature tall and/or very dense do not score highly – such as mono-dominant swamps. Swamps and eutrophic vegetation may be important for other aspects of conservation such as breeding birds, invertebrates or social-economic values and should not be judged entirely on RWPFS. Some communities may be important for one or two rare species but otherwise score low, or they may be important because they are a unique fen type of considerable intrinsic ecological interest. The BS5 *Dryopteris-Sphagnum* spp fen illustrates both. Some, such as the S4 reedbeds, may have a low mean RWPFS, but because of their wet fen location and the very extensive data set across all of the various habitats, can include uncommon plants, particularly semi-aquatic species. For instance, in a few examples in the Thurne catchment, *Najas marina* was recorded.

Figure 19a-f shows the RWPFS for each of the principal communities. The index has been calculated as the average score per sample for the community, rather than the

Figure I9a: RWPFS for the Mires and Fen Meadows, by Sub-community.

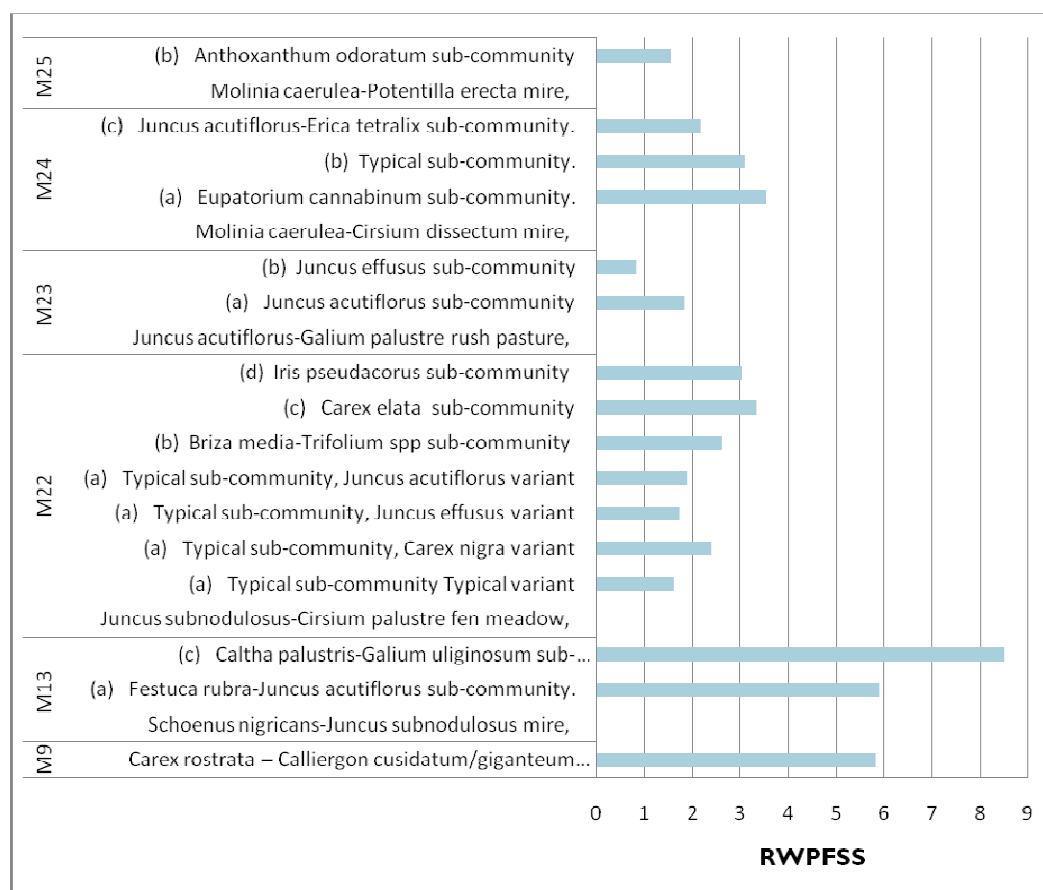


Figure I9b: RWPFS for S4 Phragmites australis Swamp, by Sub-community and variant.

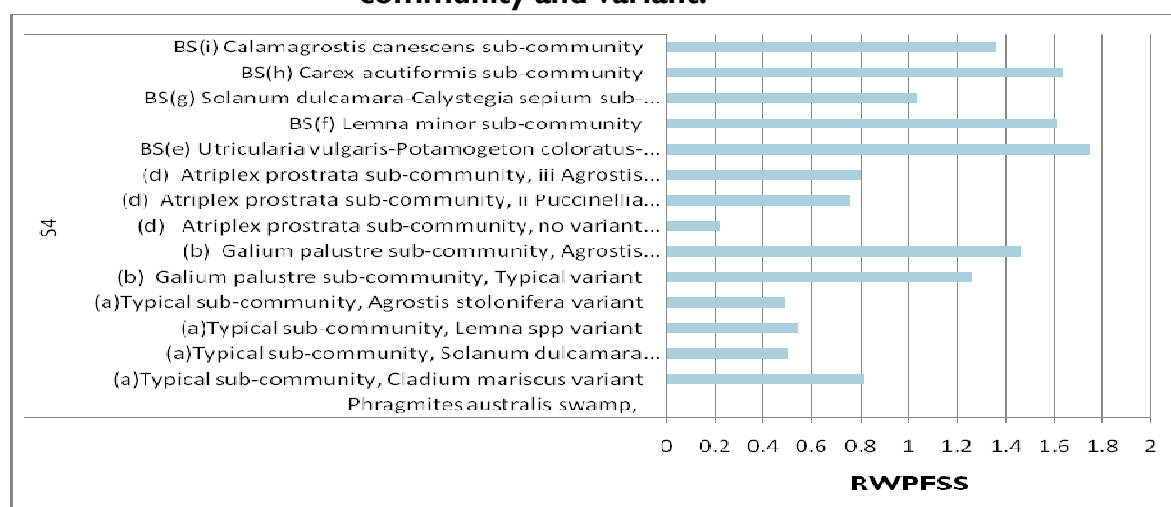


Figure 19c: RWPFS for S1, S2, BS1, S5, S6, S7, BS2 and some Intermediates.

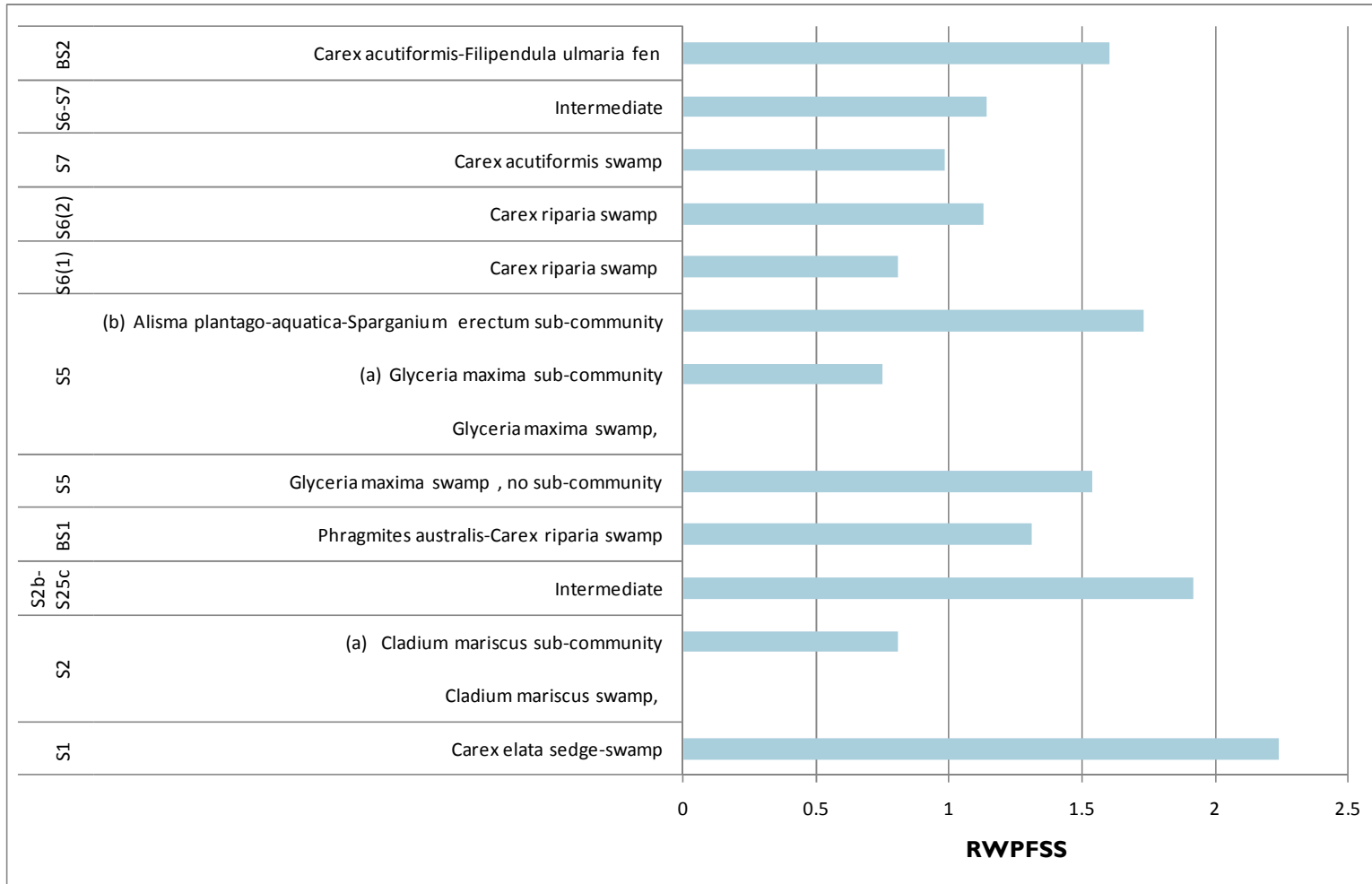


Figure 19d: RWPFS for S8, S9, S12, S13, S14, S17, S19, S20 and S21.

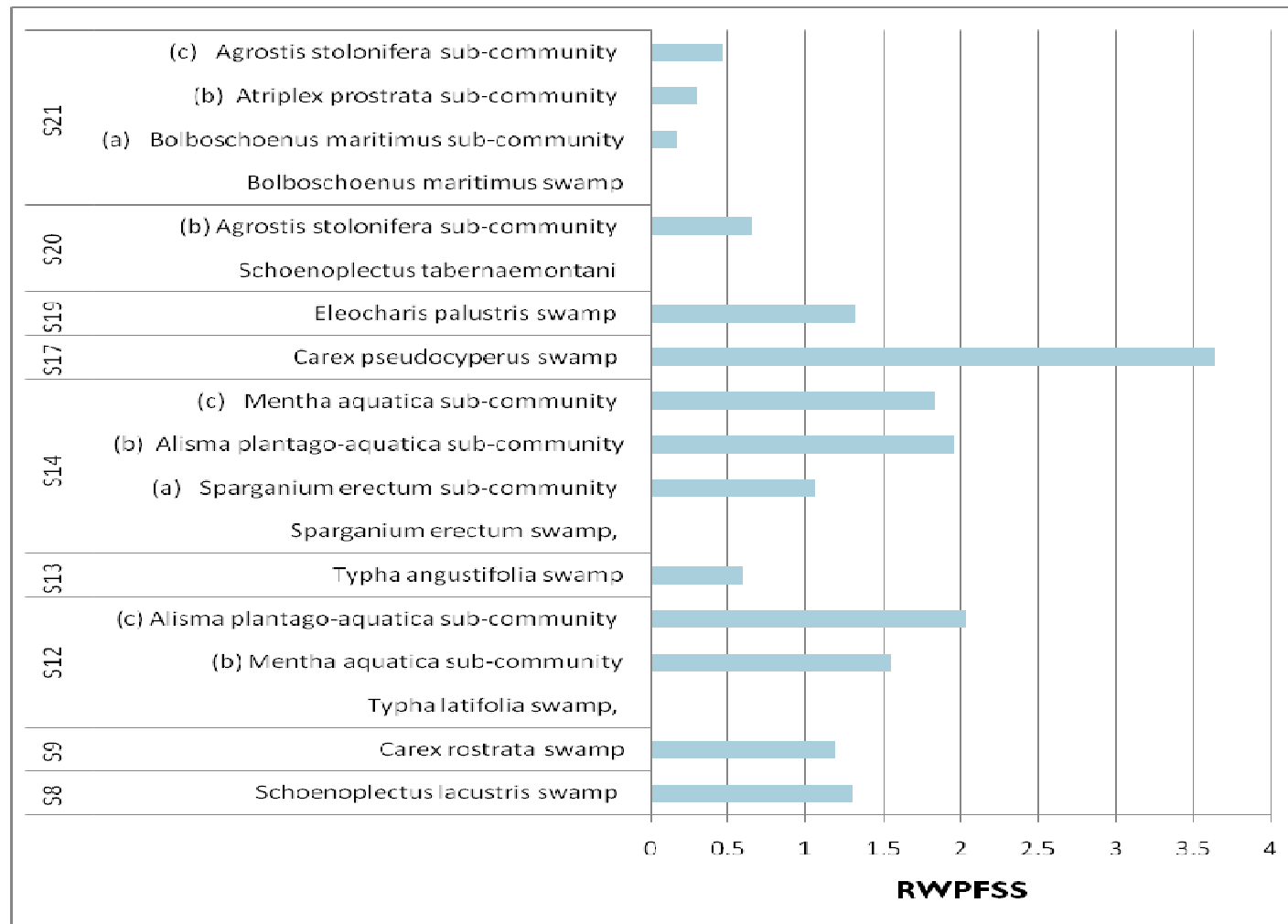


Figure 19e: RWPFS for BS3, BS4, BS5, S24, S25 and S27 Fen Types

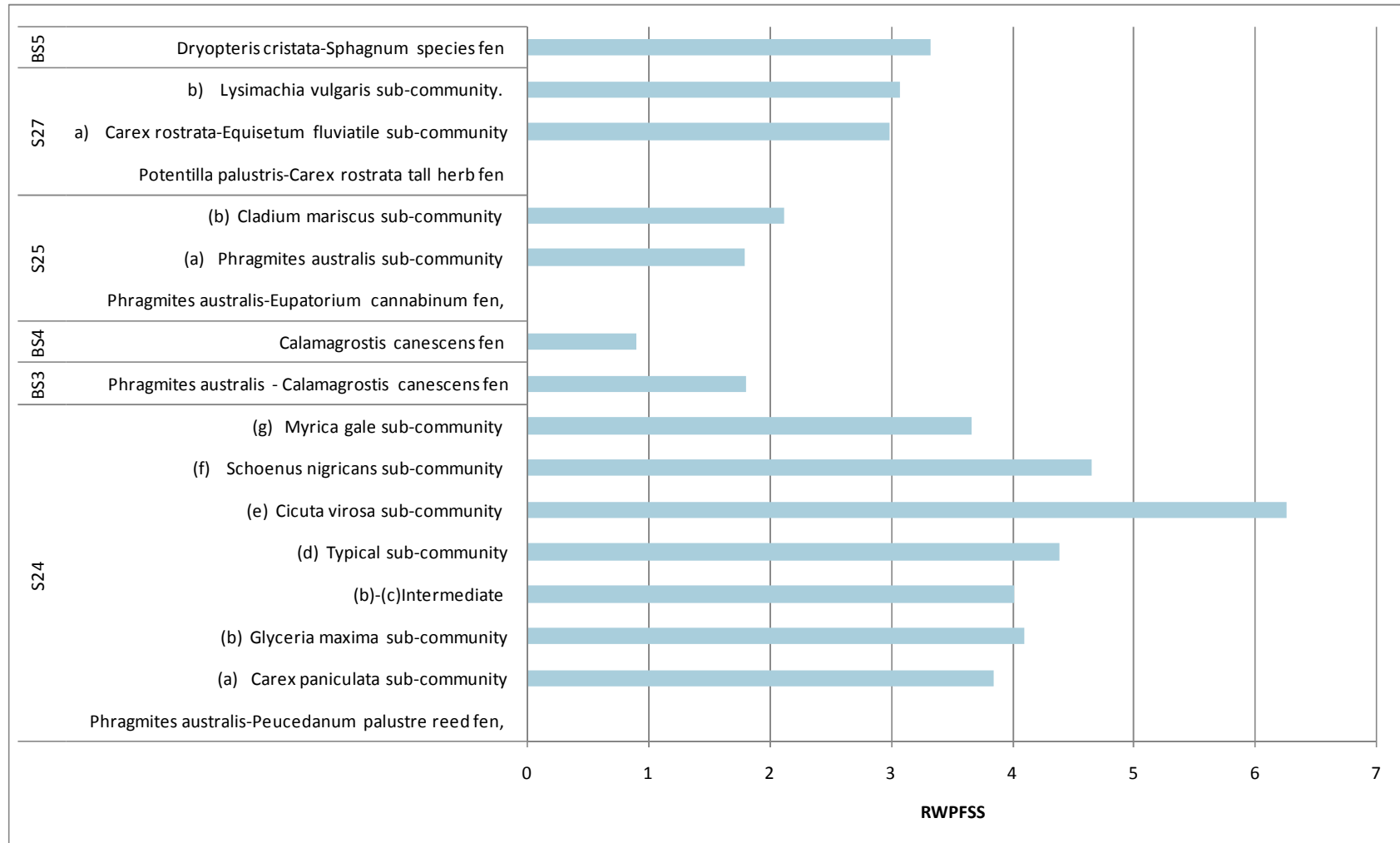
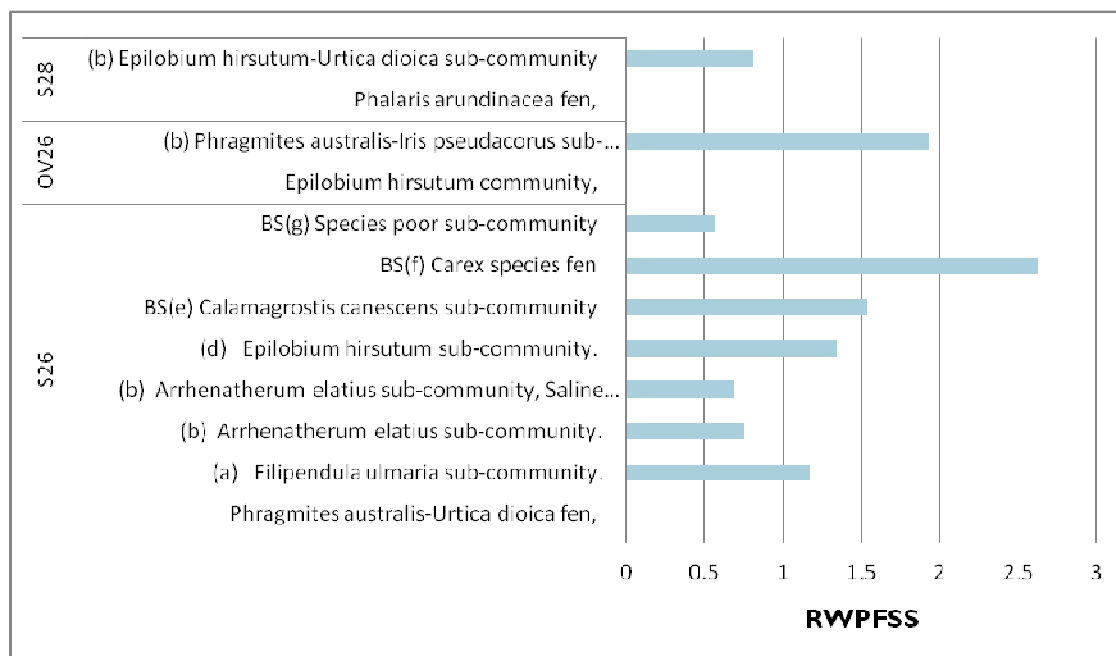


Figure 19f: RWPFS for the Core of the Eutrophic Fen Communities: S26, OV26 and S28



total for all samples. This avoids biasing the scores toward communities with hundreds of samples. Such communities have very long tails of very infrequent species which would accumulate enormous and unrepresentative scores.

Unsurprisingly, the richest of all of the vegetation types is M13 which averages a score of more than 8 per sample, with a maximum of 12.83. The next richest is the *Cicuta* sub-community of S24 with a RWPFS of just above 6. M9, with one sample, is the next richest at around 6. The fact that these vegetation types are all characteristic of very wet, low nutrient and calcareous conditions is no coincidence, and they are floristically quite closely related.

The remaining sub-communities of S24 are in the next richest group with RWPFS of 3.5-5, with the *Schoenus* sub-community being the better scoring of the group. The other main tall herb fen, S25 *Phragmites-Eupatorium* vegetation, scores around half or less that recorded by S24. The calcareous fen meadows – M22 and M24 – are reasonably rich with a RWPFS of around 3²⁹, along with the S27 fens.

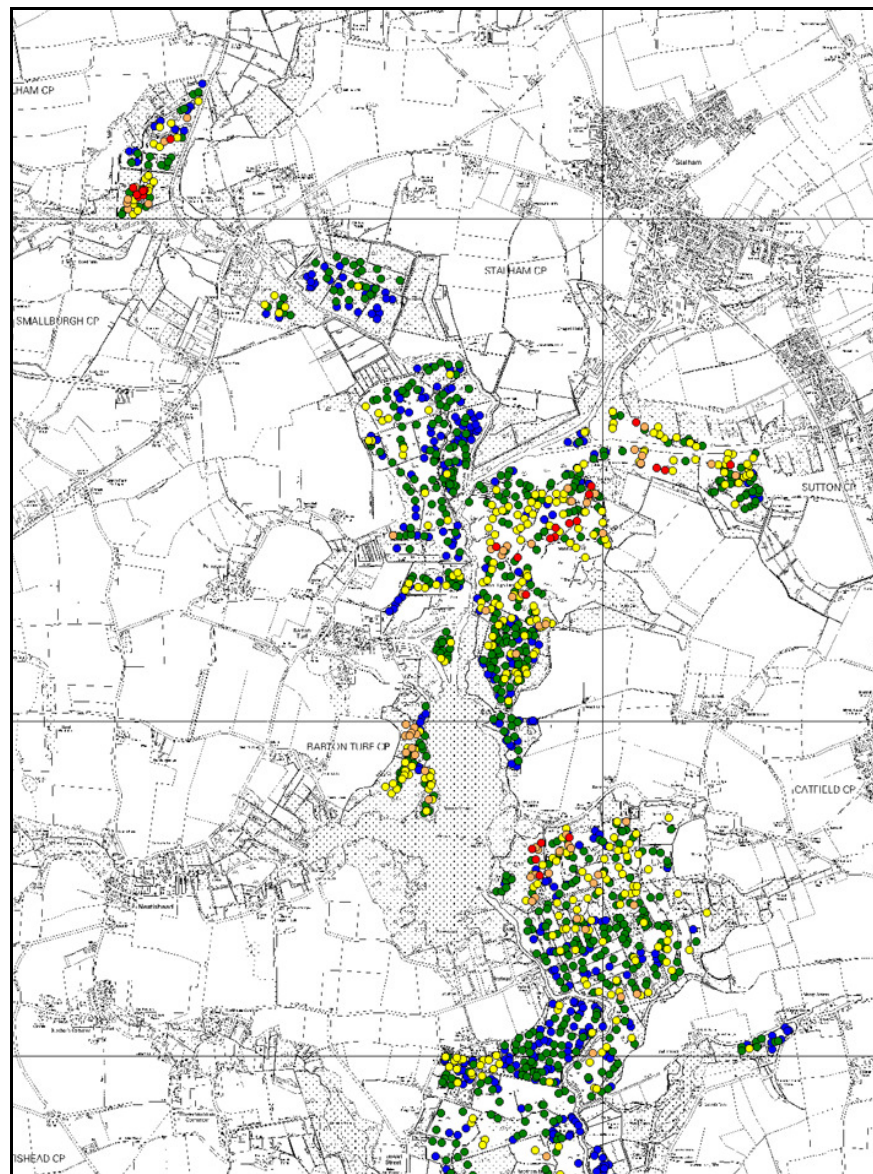
Then it is the swamp communities, which all score poorly. The S4 *Phragmites* swamps are variable, with some scoring between 1.2 and 1.8, while most score less than 1. This may reflect the wide range of substrates and hydrologies they were recorded in. The *Cladium* swamps are very poor, scoring 0.8. Most of the rest of the swamps, including pond sedge vegetation, scored less than 2. One exception is the small number of samples of S17 *Carex*

²⁹ These communities would score much better in the normal calculation of species-richness which included all species, because of the range of meadow plants in the community.

pseudocyperus swamp that scored around 3.6, perhaps reflecting the generally more open nature of this community. The eutrophic fens scored very poorly, no better than the swamps and often a lot worse with the sub-communities of S26, often scoring less than 1.

In terms of sites and valleys, high scoring samples are not spread evenly across the Broads. The Ant fens consistently have the higher scoring samples (See Figure 20), followed by the Bure. The Thurne and Yare generally have low RWPFS (Figure 21), but there are exceptions. The Waveney also scores low but has a relatively small resource outside of the rond vegetation. Full size maps for all the valleys are included on the accompanying CD.

Figure 20: RWPFS in the Ant Catchment. Note the preponderance of yellow and orange, and frequent red symbols indicative of the highest index values.



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In the Ant, Smallburgh Fen, Broad Fen Dilham, Catfield Fen, Sutton Broad Fen and Sutton Fen stand out for their inclusion of samples with a RWPFSS of 8 or more, and their overall consistently high scoring samples. There appears to be a clear coincidence of high scores with areas of wet, calcareous fen and the presence of hollows and old turf ponds. Other sites in the Ant have moderate interest while sites of predominantly species-poor vegetation are uncommon.

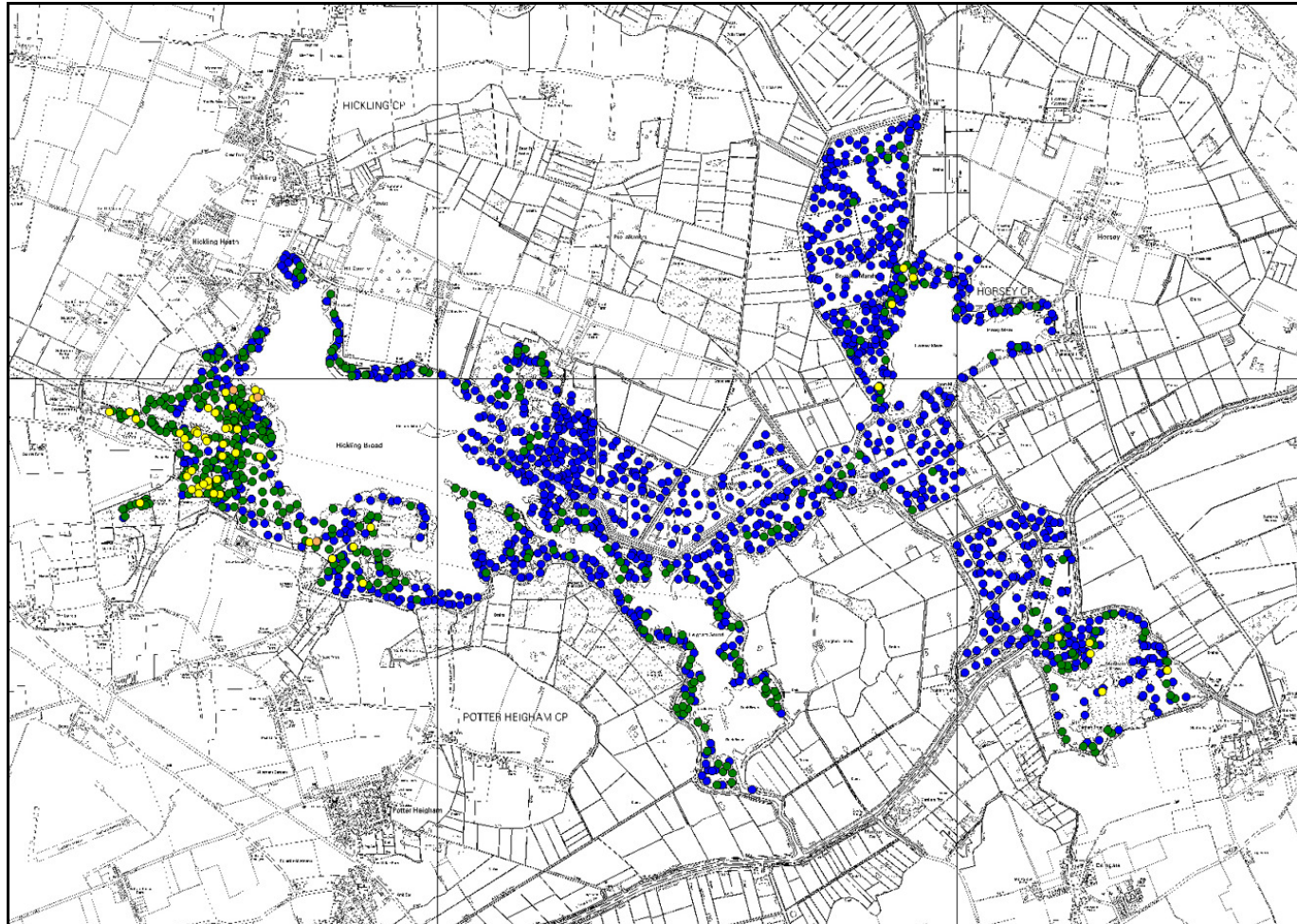
In the Bure, Upton Fen is comparable to the best Ant fens. The Ranworth and Woodbastwick Marshes have consistently high scores, and the Horning Marshes also have good representation of higher scores. Perhaps surprisingly Burgh Common matches and exceeds all the Bure sites except Upton Fen, including a cluster of samples in the highest RWPFSS category. The fen meadows on Burgh Common score well, but it is the recently excavated turf ponds which excel. The commercial reedbeds of the Ranworth Flood, being dense reed, generally score quite low but there are a number of low-to-mid and mid-to-upper scoring samples, suggesting winter-managed reedbeds can conserve a significant botanical resource. The fen meadows in the headwater tributaries score relatively poorly, perhaps because they are unmanaged or managed at low intensity.

In the Thurne, the higher scoring samples are in the fens at the west end of Hickling, and to a lesser extent the broad margins at the north end of Horsey Mere, around Martham Broad and either side of Heigham Sound. Much of the rest of the catchment consists of species-poor *Cladium* beds, especially on the Brayden Marshes, and species-poor reedbeds on Hickling and Heigham Holmes.

In the mid and Upper Yare, the higher scoring sites are the fen meadows on the mid-valley margins. The species-rich fens at Church Farm Marshes, and parts of Strumpshaw Fens near to the highland margins also score well, although compared to the Ant and Bure these are still only moderate. Much of the rest of the valley is low-scoring eutrophic fen or dense reed swamp managed for birds.

The lower Yare and most of the Waveney, both of which are mostly rond vegetation, are low scoring. The fens along the valley margin at Oulton have samples with moderate RWPFSS.

Figure 21: RWPFS in the Thurne Catchment. Note the preponderance of blue symbols indicative of species-poor vegetation, typically reed and *Cladium* swamp. Richer samples are generally along the western margins of the main broads.



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Structural Diversity

There is diversity, too, in structure. The plant architecture of Broadland fens is determined by three components:

- **The juxtaposition of plant communities of different physical forms.** The patchwork of fen communities described above produces structural diversity at the meso-scale, arising from low-growing mires and fen meadows being juxtaposed with tall herb fens, or domed *Sphagnum* mires juxtaposed with swamps and tussock sedge fen, and so on. Eco-tones are created between fen vegetation types which are of particular ecological interest. The topographical variation in many fen surfaces (peat cuttings, embankments and the margins of dykes for instance) adds significantly to this meso-scale structural variation.
- **The species composition of the communities.** The more diverse the plant community, the more diverse its structure. This provides micro-scale structural diversity. Vegetation types with the greatest micro-scale habitat structure are those which have a rich ground layer of bryophytes and small herbs, a mid-layer of sedges, rushes and herbs, and an upper layer of helophytes and tall herbs. Structural diversity is especially enhanced where the community includes tussock species such as *Schoenus* and *Carex paniculata*, which can themselves form the substrate of other plants. S24 *Phragmites-Peucedanum* fens are one of the prime examples of these structurally diverse fens. Mono-dominant swamps such as S4 tend to be much more uniform in their architecture, although species such as *Cladium* with a denser growth from the base and persistent leaves provide more physical structure in their swamps than thin-stemmed crops such as *Phragmites*.
- **Management regime.** Management can provide a controlling influence on structure at the macro-scale, through the patch size that is cropped. In this sense, grazed fens with a seemingly random and progressive cropping pattern that generates small-grained mosaics may provide the best structural diversity, although the final habitat structure can be very dependent on the particular community type and the stocking density. Large-area crop harvesting provides low structural diversity. The least structurally diverse fens of all are those that are not regularly managed. Taller, more competitive species tend to be ascendant and upward draw of the vegetation in response to competition for light provides a very uniform stand which can be many hectares in extent.

When the structural diversity arising from patch management is combined with the structural diversity arising from community composition and the juxtapositioning of plant communities with different plant architecture, the result is a habitat of great physical complexity.

This variety is amplified by the further juxtapositioning of the fens with other Broadland habitats, such as scrub and woodland and the ramifying network of dykes. Structural diversity is therefore one of the key attributes which defines the conservation value of Broadland.

Such structural diversity is of critical importance to invertebrates. Lott et al (2010b) found that a more diverse vegetation structure increased the diversity of invertebrate assemblages in a survey conducted in parallel to this vegetation survey. An element of scrub and sedge tussocks in the vegetation was particularly valuable.

Whether this diversity is declining, in response to wider changes in Broadland, is not certain. There is no comparative data, but if the trends regarding cessation of management, eutrophication and the reduction in extent of some key communities of

the hydrosere proposed above are substantiated, the concomitant loss of structural diversity seems inevitable. These losses have to some extent been mitigated by capital works such as scrub removal, the excavation of turf ponds and shallow peat cuttings and the reinvigoration of fen management by the commercial cutting industry and the fen harvester.

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6. CHANGE IN THE BROADLAND FENS

6.1 Summary of Change

Throughout this report, the likelihood of significant change in Broadland fens has been discussed. To summarise, the results of the current survey suggests the following changes have taken place:

- An expansion of eutrophic tall herb fens.
- An expansion of tall herb fens dominated by, or with a great abundance of, *Carex riparia* and/or *Carex acutiformis*.
- An increase in *Phragmites australis* so that it is ubiquitous in almost all fen, swamp and mire communities. Reed-based fen appears to have succeeded a variety of communities including *Cladium* and *Glyceria*.
- An increase in the extent and range in communities showing a brackish water influence, from the mild influence shown in fen compartments to the presence of true saltmarsh communities on the ronds.
- A decrease in *Glyceria maxima* communities, especially in the Yare, where there appears to have been wholesale change in much of the valley floodplain.
- A reduction in the extent and quality of S24 tall herb fens, partly as a consequence of the expansion of the above vegetation types. There are also some questions as to the continued presence of Wheeler's *Peucedano-Phragmitetum caricetosum*, most properly considered an S24 community.
- The truncation of the hydrosere, with the loss of much of the aquatic and pioneer swamp phases, the early secondary swamp communities such as *Carex paniculata* fen and the dryland to floodplain fen transition phase. These now appear to only exist in fragmented and degraded examples.
- A loss of all fen types including the middle hydrosere floodplain tall herb fens to scrub and woodland over-growth.
- Probable loss of structural diversity of the fens consequent upon the above changes.

These very broad conclusions are corroborated by known environmental changes in the Broads, the main ones being:

- The general eutrophication of the rivers, broads and to an extent the groundwater³⁰ that feed the wetland communities.
- The wholesale change to and often abandonment of fen management.
- The relentless march of scrub across the landscape
- The direct impact of coypu on swamp vegetation and subsequently the increase in boat traffic and recreational use that has eroded the margins of the broads and prevented recovery of the swamps.
- The succession of turf ponds, fen dykes and other topographical variation.

³⁰ Eutrophication of groundwater is much more difficult to establish, although the fact that many of the Broads valleys are flanked by permeable drift deposits carrying intensive agriculture makes this highly likely. Of more doubt is the direct contribution of these groundwater sources to the hydrology of floodplain fens.

- An increase in salinity of the lower reaches of the rivers is increasing in terms of the frequency and duration of salt incursions, along with evidence of increasing brackish influence in the fen compartments of the floodplains.

Evidence of hydrological change is much more difficult to ascertain and probably varies greatly between fen compartments. Climate change (discussed below) may accelerate some of these direct environmental changes.

Although the evidence for change adduced above is largely circumstantial, there can be little doubt that change is occurring in the fens, and that most of this change is negative. This was recognised by Lambert (1965) who stated “Major changes in the structure and composition of the vegetation have taken place well within living memory with increasingly rapid replacement of one community by another...” and “...the whole Broadland scene is at present at a very critical transitional stage.” Since this was written, there has been a further 45 years of change.

6.2 Autogenic Change

One source of change that is frequently overlooked is autogenic change within the fen communities. Essentially successional, autogenic change refers to the process whereby the composition of plant communities alters over time, even when all environmental variables are stable. An example of this is the development of *Sphagnum* communities which grow amidst rich-fen by building the fen surface and acidifying their surroundings, triggering the onset of ombrotrophic bog conditions. Autogenic succession is responsible for the change in vegetation types in the turf ponds described by Giller and Wheeler (1986).

Drying-out and accumulation of nutrients may be the most significant autogenic processes in floodplain fens. In unmanaged sites, this is mostly through the deposition of above ground plant remains. In very wet conditions, this leads to peat accumulation which will eventually elevate the fen surface above the water table. As the fen surface is increasingly disassociated with the water table, the community shifts to drier types. Further accumulations of litter are readily broken down and the nutrients made available at the fen surface, encouraging the development of eutrophic communities. Invasion of the community by non-fen species and woody plants is facilitated. This can have significant consequences for the fauna of fens. For instance, Lott et al (2010b) found that the overriding influence on the diversity and quality of fen invertebrates was hydrology. The best invertebrate communities were associated with very wet mires with stable water regimes. Drying of the fen surface caused a change of invertebrate assemblages towards damp meadow and marsh species. Similarly, drying out through autogenic change in *Phragmites* swamp is thought to have been responsible for the reduction in breeding birds of wet reedbeds such as bittern³¹.

The ultimate and more familiar consequence of autogenic change is the development of scrub and woodland at the expense of all types of open fen. The relationship between scrub development and community types is complex. It is certainly not restricted to dryer fen types, although scrub encroachment may be more rapid in these. Deep beds of *Cladium* litter can be as inimical to the establishment of tree seedlings as for fen species (Lambert 1965), while hover with its constant water level,

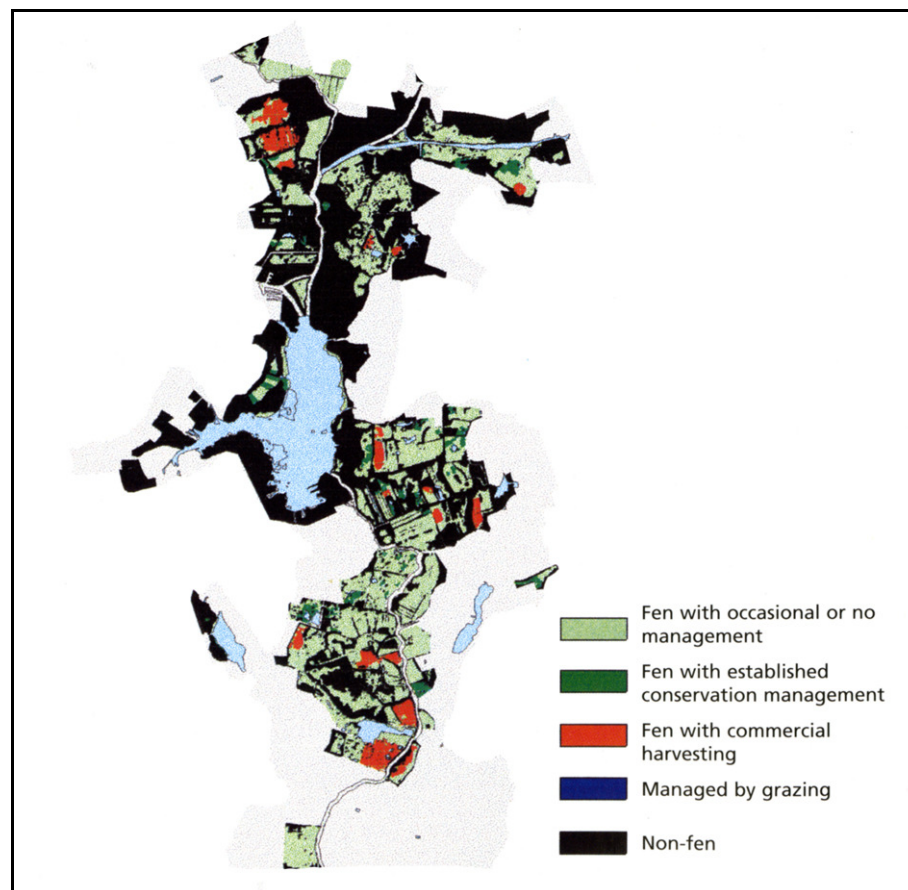
³¹ This led to a major partnership project funded by the EU to restore wet reedbeds by combinations of water level management and ground lowering. This restoration work may in part be responsible for the proliferation of wet S4 *Phragmites* swamps and perhaps the development of some of the new S4 sub-communities and variants proposed here.

or very wet tussock fen with its dry tussock tops, can both be fine seed beds for scrub.

6.3 The Role Of Management in Arresting Change

Management is critical in arresting autogenic change by prevention of above ground litter accumulation and exclusion of tree seedlings. However, by the middle of the century, traditional management had greatly declined (Lambert 1965, George 1992). Figure 22 shows the level of management operating in the Ant catchment by the end of the century. Tolhurst (1997) presents similarly dispiriting maps for all of the valleys. Much progress has been made since then in restoring derelict fens, but the task of bringing all fens back into management remains challenging.

Figure 22: Levels of Management in The River Ant at the End of the Twentieth Century. After Tolhurst (1997). Areas in black are mostly dense scrub and woodland.



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Even where fen vegetation is cropped intensively, elevation of the peat surface can continue through the accumulation of root matter, especially in communities dominated by rhizomatous species such as *Phragmites* or *Cladium*. Autogenic change may therefore continue, albeit at a reduced rate, in well managed sites. Hence Wheeler and Giller (1986) suggested that the *Peucedano-Phragmitetum caricetosum* would progress to dryer, less species-rich fen types even when cropped regularly.

Management can reverse this change through the excavation of shallow turf ponds which re-invigorates the succession, re-creating wet fen types.

6.4 Understanding the Assembly Rules for Important Fen Types

There is an assumption that if the hydrological regime associated with a certain community (e.g. S4) changes to the hydrological regime associated with another community (e.g. S24), the floristics of the original vegetation type will track this change, in this case developing a stand of typical S24. This assumption needs testing, however, as there is slim evidence that plant communities assemble themselves in such a predictable way following environmental perturbation. There is some evidence (e.g. Fojt and Harding 1991) showing how complex fen communities degrade to simpler or non-fen communities, but little evidence that demonstrates how high quality communities can be assembled from dryland or species-poor precursors. Degradation from species-rich to species-poor fen is likely to be a straightforward process of subtraction, an ecological equivalent to last man standing. The process of simplification can therefore be independent of its surroundings, taking place wholly within the vegetation plot³². Assembling species-rich communities from a species-poor precursor is wholly different, being an additive process presumably requiring a viable seed bank or external seed rain and vegetative growth from adjacent stands. The intuitive proposition that community change is bi-directional has only been demonstrated for management treatments in stable environments (Godwin 1941). The way in which ecologically important vegetation types assemble themselves, and how this can be manipulated by management, is of central importance to fen conservation.

6.5 Inertia and Resistance to Change

A further complicating factor in understanding the impact of environmental change is vegetation inertia, whereby the response of a plant community to a shift in environmental parameters may take decades to reach any kind of stable equilibrium due to either the compliment of long lived perennials in the vegetation, or because of the capacity of the substrate to buffer the change. Inertia therefore provides further uncertainty in defining outcomes.

6.6 Climate Change and the Fens.

Neale (2009) summarises the current climate change predictions for the Broads as warmer wetter winters and hotter, drier summers, together with an increase in sea levels. Rainfall intensity will increase, as will extreme events such as droughts and storms. The resulting changes in the Broads are thought to be:

- An increase in the area of coastal and saline habitats.
- A reduction in the area of freshwater habitats.
- An increase in the frequency and duration of saltwater ingress.
- Reduced available water resources.
- Damage to wetland habitats due to increased flooding and drought stress.
- The loss of some species, currently present in the Broads, along with the arrival of others, the latter including non-native or invasive species.

³² Although it is true that “degraded” fens are supplemented externally by the invasion of dryland species or scrub, this is not germane to a discussion of fen communities.

Neale's last point refers to the shift in climatic zone in which Broadland sits. This will favour fen species more closely associated with Continental type climates, and disfavour species more typical of the north and west of Britain. Broadland fen vegetation types may therefore shift to have closer affinity with European wetland types. The extent of communities such as M23 and M25, typical of Atlantic regions, may decline. There may be other broader changes to the local environment arising from climate change, particularly with regard to agriculture, which may have consequential effects upon the wetlands. There may also be other changes which have indirect or multiplier impacts, such as increases in local populations or recreational pressures.

How these broad predictions eventually affect the fen vegetation of Broadland depends upon:

1. The specific changes to hydrology, in terms of water quality and water quantity, within individual fen compartments. The above review has shown quite clearly that the nature of fen vegetation communities is determined by hydro-chemical regime, and that small differences in such a regime can result in significant shifts in community type, its quality and its extent. However, gross changes in catchment hydrology may not map directly onto changes within compartments, as a whole host of factors mediates how a river or groundwater regime is expressed within the rooting zone of a complex fen surface.
2. Similarly the specific climatic changes experienced within individual fen compartments. Regional changes to climate may not be translated in a straightforward way to changes within fen vegetation. A wide range of factors condition the micro-climate experienced by fen vegetation, including the behaviour of the local water table. Hydrology and climate consequently have a two-way interactive link which is potentially very complex.
3. The degree to which site management can mitigate hydrological and local climate change, for instance by amending mowing regimes, grazing patterns, water level management and so on.
4. The degree to which catchment management or watercourse management can mitigate climate change by, for instance, reducing salt incursions or reducing the impact on summer water tables.

It is almost certain that without adaptation strategies, climate change is likely to have profound impacts on the fen vegetation of Broadland. How this affects individual fen compartments is less certain.

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7. ISSUES REQUIRING FURTHER RESEARCH

7.1 Improving the Evidence Base

Although *broad* change in the fen vegetation has been corroborated above with *broad* change in environmental conditions, what cannot be undertaken with the current evidence base is linking *specific* change in particular vegetation types in particular places, with *defined* change in environmental variables operating across those stands of vegetation. This requires detailed monitoring of vegetation and environmental parameters, and specific research on historic change, both of which are currently lacking. Improved understanding could be established through the following;

- Identification of detailed historic vegetation data sets linked to specific locations, for example, Lambert's transects of the Bure and Yare. These could be compared with data in this survey, or with the results of specific new comparative studies which replicate the location, method of data collection and analysis of the original work. Some historic studies may be in the literature, but others will be in reports, the files of conservation organisations or personal archives.
- The re-analysis of perhaps the only other comparable broadscale survey, that undertaken by Jo Parmenter (1995), so that her data set is comparable to this. It might then be possible to identify shifts in the quantity and distribution of particular community types. This would be a substantial task.
- Particular research on aspects of fen ecology which would inform our interpretation of some of the changes proposed. For instance, the need to understand the autecology of *Carex riparia* and *Carex acutiformis* has been referred to above. The impact of different management treatments, understanding autogenic change in various fen communities and the responses of different fen vegetation types to enhanced nutrients, would also provide valuable evidence which explained some of the observed changes.

While it may be difficult now to establish incontrovertible evidence regarding past change, the foregoing discussion makes very clear the need to start and maintain monitoring schemes to identify future changes to the fen resource with more certainty.

7.2 Improving Understanding of Climate Change on Fens

Although the regional impacts of climate change will be profound, the consequential impacts on Broadland fens are not understood. Some work under other parts of the fen ecological survey (Telfer 2010) has made progress in devising indices of change in invertebrate communities that relate to climate change, but no work has been undertaken for the botanical resource. Formulating adaptation strategies are therefore problematic.

Primary among the data requirements are an understanding of how climate change will affect the hydrology of individual fen compartments, and how it will affect the micro-climate of such areas. For most fen areas we have a relatively shaky grasp of these parameters for prevailing conditions, let alone the ability to forecast change. Understanding baseline conditions is a particular priority. The hydrological work associated with the Review of Consents process is a significant step forward in developing such an understanding, but concerns relatively few sites. Hydrological

models are not always at the scale required for understanding ecological change, but this work and previous hydrological casework provides a starting point.

There is also uncertainty in linking hydrological (and climatic) change to vegetational change and this has been discussed above. The mediation of management in this process is also clearly central to any climate change adaptation strategy, and needs to be clearly understood.

Only when we understand these issues can the process sequence of change in climate > change in specific environmental parameters > change in specific vegetation types be mapped onto the Broadland fen compartments. Mapping vegetation outcomes is the first stage of any adaptation strategy. Developing a range of scenarios based on different management interventions would be the basis of any Action Plan for such a strategy.

This vegetation survey provides the baseline data for any prediction of climate change impacts. It provides quantitative data on vegetation composition which allows numerical modelling of change. By mapping this data onto predictions of environmental change and vegetation response, it may be possible to predict plant community outcomes, and help formulate the management policies required by the climate adaptation strategy.

Probably the most appropriate framework to use for climate change modelling would be one based on Wetmecs. A Wetmec (contraction of Wetland Mechanism) summarises a particular hydrological regime which supports one or more wetland types. Wetmecs were developed by Wheeler et al (2009) to provide a framework for describing the hydrological functioning of wetland sites, and how they might respond to changes in key hydrological parameters.

The strands of any climate change research programme would therefore include:

1. Developing a precise understanding of current hydrological and micro-climate parameters in the fen compartments.
2. Using this to map the current Wetmecs of the Broads compartments.
3. Translating regional climate change predictions to changes in environmental parameters within fen compartments.
4. Translating these changes to potential changes in Wetmec type of condition for the Broads compartments.
5. Developing a more precise understanding of the eco-hydrological relationships of fen vegetation communities, including the less valuable fen types into which more valued types might change.
6. Developing a more precise understanding of management of fen vegetation.
7. Based on the current vegetation data set, mapping of fen vegetation change under a variety of management strategies.

It is unlikely that steps 1 and 3 could be undertaken for all fen compartments across the Broads. Selection of a number of sites that were considered representative and extrapolating the results across the Broads may be more efficient, accepting that this introduces a measure of uncertainty.

7.3 The Influence Of Management On Fen Community Type

The way that management treatment affects fens is described in some detail in Rodwell (1991b, 1995, 2000), Wheeler and Shaw (1987), Shaw and Wheeler (1990),

and in terms of species-richness, Wheeler and Shaw (1991). More of a Broadland context is provided in Lambert (1965), George (1992), Tolhurst (1997) and Moss (2001). It is beyond the scope of this report to undertake a comprehensive review of fen management – there may be more recent information in the literature, particularly from abroad.

There is a paucity of data on grazing in fens (as opposed to heaths, grasslands or landscapes such as the New Forest e.g. Putman 1986), despite the widespread interest and recent initiation of large grazing schemes. Grazing is a very different process than mowing. The impact of its introduction to previously ungrazed sites requires research. The impact of grazing on fen vegetation types which were historically not or only rarely grazed is a particular priority. The impact of grazing on individual species of architectural importance, such as *Cladium* or the Sphagna, is needed, and the particular response of rare species to grazing management is also important when designing site management. It may be especially important to tease out the subtleties of grazing management – stock type and grazing density, as a purely binary approach with grazed and ungrazed categories is far too simplistic.

The knowledge base relating to mowing management is more developed and is summarised in the above references. We know broadly how to maintain species-richness and how to maintain the broad habitat categories, but this is largely directed at maintaining traditional habitats such as reedbeds, sedge beds, litter and so on. We have relatively little knowledge of minimum management regimes to sustain particular features, and relatively little understanding of optimal and sub-optimal regimes for particular species of conservation concern.

ELP (2010a) attempted to address some of these issues directly by examining the effect of management on five sites in Broadland. Data collected for this survey was compared with previous data sets. Firm conclusions were difficult, because the earlier data sets were too sparse and samples inaccurately located. In addition, management records were often insufficient or too inaccurate to interpret the change that was recorded. However, some broad conclusions about the impact of scrub clearance and grazing, two treatments widely applied in the Broads in recent years, were made.

When compared to adjacent long established fen, areas cleared of scrub consistently had fewer desirable fen species, had less woody species and had more frequent aquatic and semi-aquatic species. In sites where *Sphagnum* species occurred, they were less frequent and abundant in areas cleared of scrub than in the adjacent fen. There is an implication that scrub clearance takes the hydrosere succession back several stages to wetter fen types. Typically, areas cleared of scrub are very open, and are at the early stages of fen plant community development. Removal of the tree canopy often involves significant disturbance of the surface (which may in particular affect Sphagna), especially if roots are removed, and may include some compaction. The subsequent successional direction of plots subject to tree removal is not clear, although data used in the study from one valley fen site outside of the Broads area indicated that the species-richness and quality of more mature post-scrub fen communities can be great.

The effects of grazing were less clear and seemed to vary greatly between sites, perhaps reflecting variation in grazing density and seasonality. Overall, the impact on desirable species and those indicative of high nutrients varied between sites without a pattern. Aquatic and semi-aquatic species were more diverse following introduction of grazing, and on Sutton Fen several pioneer species of open ground were recorded after grazing was introduced.

These conclusions are very tentative and based on a small number of sites with data that remains difficult to interpret with certainty. It is made very clear in ELP (2010a) that to understand change related to management, there is no substitute for specific research or data-rich monitoring plots recorded before and after management is altered.

Restoration ecology is not clearly understood in fens, especially rich-fens. Particular gaps in our understanding include the impact of scrub removal and the direction of successional change following scrub removal. Which types of scrub yield which types of fen, and how the outcome can be manipulated by other management activities, is not clear.

Of particular interest is the management of the succession by stripping of surface layers, ground lowering and turf ponding. There has been a great deal of success in creating new turf ponds, but some have not met conservationists aspirations in that they have colonised by reed or not re-vegetated at all. There is more work to do on turf pond succession (Giller and Wheeler 1986). The life expectancy of turf ponds also needs elucidation in order to inform any strategy regarding sustainable and cyclical management of the fens by peat removal. Central to this is the method and rates whereby peat infills shallow water bodies.

The restoration of the full hydrosere sequence is important in reconstructing the habitats of the Broadlands. Now that coypu are no longer an issue, increasing effort is being made to reintroduce the reed swamp fringe of the broads. Current efforts are hampered by relatively little research into techniques and their subsequent outcomes, and even less on the ecological processes that control swamp extension into shallow water bodies.

The above discussion and comments made elsewhere in this report suggest the need for the following management-related research:

- The impact of different stock types and grazing regimes on fen communities and species.
- Vegetation change in different tall herb fens consequent upon the cessation of management.
- The precise impact of different mowing regimes on Broadland vegetation types and on species of conservation concern. In particular, devising management regimes which optimise the balance between resources expended and botanical species conserved for particular vegetation types.
- Inertia and resilience to environmental perturbation in different fen communities.
- The role of scrub clearance in regenerating fens, including the kinds of fen expected from clearance of different types of wet woodland and their long term successional path.
- The impact on different fen types of the use of large machinery for management operations, and a comparison of machinery as against traditional techniques.
- Methods for regenerating pioneer swamp and fen communities.
- Managing fen systems through cyclical shallow peat excavation, and the autogenic change brought about by peat and litter accumulation.

7.4 Broadland Fens and the NVC

There has been much comment above regarding the adequacy of the NVC to describe the variation of fen vegetation recorded in this survey. In their review of the NVC, Rodwell et al (2000) acknowledge sections of the NVC may need reconsideration in the light of additional sampling. They suggest that around 50 possible new NVC communities have been defined by users since publication of the first drafts. The most numerous gaps they identify appear to be in aquatic open water communities and those associated with water margins and springs. Their review has not helped interpret the new communities described in the *Results* section.

This survey has identified a range of vegetation types that are not adequately treated in the NVC and may give rise to new communities. These are principally:

- Species-poor reed fens, particularly those closely related to S4 *Phragmites australis* reedbeds. The data suggest that the diversity of S4 reed types is under-represented in the NVC.
- Species-poor S2 *Cladium mariscus* swamp, in particular its transitions to S4 *Phragmites australis* reedbeds and to S25c *Phragmites australis*-*Eupatorium cannabinum* fen, the *Cladium* sub-community.
- Fen vegetation associated with brackish conditions, including reed fen with *Agrostis stolonifera* and the transitions between S4 *Phragmites australis* reed fen and true salt marsh communities.
- The *Dryopteris cristata*-*Sphagnum* species vegetation, proposed here as a new sub-community of S24 *Phragmites*-*Peucedanum* tall-herb fen. Wheelers (1980a) *Peucedano-Phragmitetum caricetosum* should also be accommodated within S24, as acknowledged by Rodwell et al (2000).
- Eutrophic fen communities, particularly S26 *Phragmites australis*-*Urtica dioica* fen and OV26 *Epilobium hirsutum* community, the latter being a true fen community and seemingly misplaced in the OV section of the NVC scheme.
- The position in the NVC of vegetation types rich in *Carex acutiformis* and *C. riparia* needs to be reconsidered, particularly the adequacy of S6 and S7 to represent this vegetation.

The integrity of these new communities requires further examination and review in a national phytosociological framework.

It was not possible to review the NVC treatment of some of the mire and fen meadow sections. This requires a full phytosociological treatment of the data rather than a classification essentially using the NVC as a framework. It also requires analysing the Broads data in the context of a national data set, as these are national communities. The data herein is available for this kind of analysis, but it is beyond the scope of the current report.

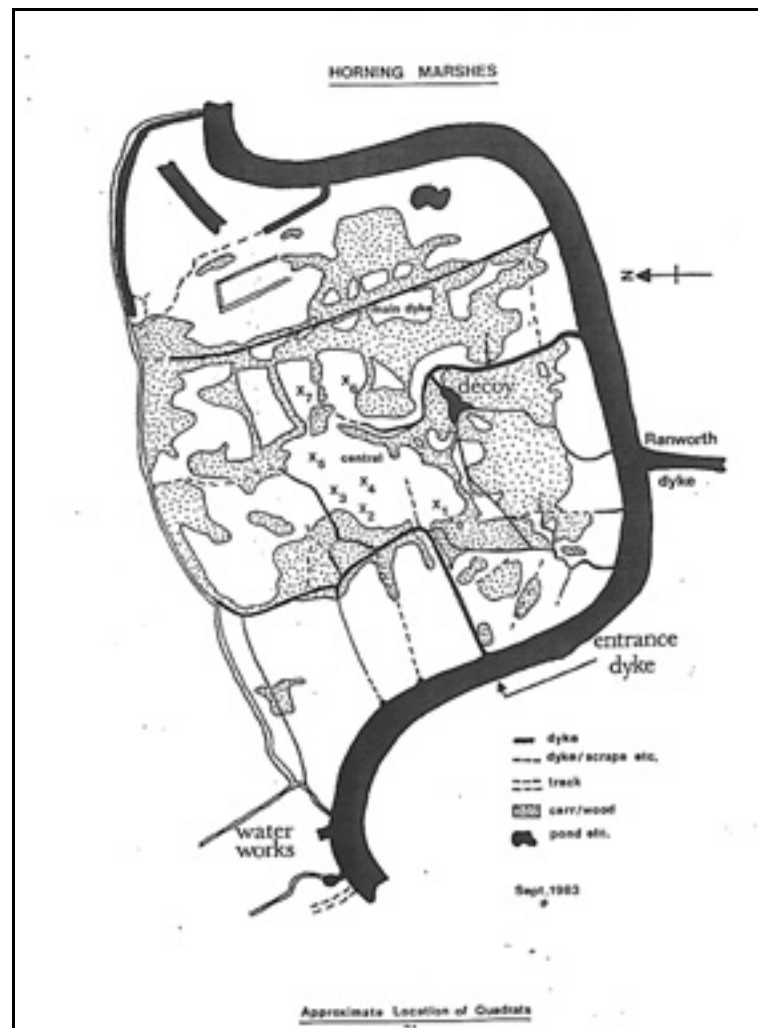
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8. ADDING VALUE TO THE VEGETATION SURVEY DATA SET

8.1 Surveillance and Monitoring.

There is relatively little fen vegetation monitoring taking place in Broadland. The Broads Authority laid out some monitoring plots in the 1990's, but these have not been re-recorded since the responsible officer left the Authority. Some could probably be relocated (Figure 23). Individual organisations may be undertaking their own monitoring but the number of schemes is thought to be low. The lack of detailed and consistent monitoring of Broadland fens was identified in the recent pilot study of change (ELP 2010a) as a major barrier to understanding the impact of management on fen vegetation. It is also cited consistently in this report as a major gap in evidence describing change in the fens.

Figure 23. Gary Kennison's Monitoring Plots at Horning Marsh.
Courtesy of the Broads Authority.



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There are wider requirements for monitoring associated with regional or national concerns such as climate change. At the national scale, the Countryside Survey

attempted to use standardised repeated vegetation surveys across the UK as a monitoring tool to evaluate change (Bunce et al 1999a, b, Firbank et al 2000) but the scheme was rather broad and used vegetation categories which are different from, and difficult to relate to, those of the NVC or any other previously recognised plant community system. Although climate change is a key issue with significant impacts predicted for the Broads (Neale 2009), only recently have monitoring plots started to be laid out in order to directly assess change that may arise (such as those at Woodbastwick Marshes, Rick Southwood pers. comm.).

Historically, the plots that were established in Broadland were located on a rather ad-hoc basis, determined by personal knowledge of the fen resource or on the particular needs of a local site. The comprehensive description of Broadland fens provided by the data in this report now allows the establishment of a fen monitoring network based on a more rigorous analysis of the distribution and composition of fen types. A network of monitoring plots which ensures coverage of the main fen types of interest, and encompasses a reasonable geographic spread across the region, is now possible.

Two types of monitoring would be helpful in the Broads:

Surveillance Monitoring: In this kind of monitoring, the overall condition of a natural resource is kept under review. Condition can include a range of factors including extent, quality (species-richness, representation of rare species), and direction of travel of the habitat or community. The approach requires wide geographical coverage and the inclusion of all significant vegetation types. It also requires linking with other data sets in order to interpret any changes identified.

Surveillance monitoring does not have a specific question to answer or a specific time frame. It aims to identify broad changes in the fens, changes that could be in response to any underlying environmental perturbation. It is less likely to identify very detailed change in individual sites, and depends on the integrity of the network rather than on individual plots.

This survey would be the primary tool in planning and locating the surveillance monitoring plots. It could be used to determine the coverage of plots among the NVC communities, the scatter of plots among the five valleys and the location of individual plots within fen compartments. It would also provide the context of each plot, that is, the mosaic of fen communities within which the monitoring plot sits. Finally, the survey should allow plots to be grouped in transects which cross environmental gradients or stratified according to management regime, allowing more accurate interpretation of the results.

As an alternative to permanent plots, it is possible to undertake surveillance monitoring through repeated, detailed and broadscale surveys such as this fen survey. Changes in the extent and quality of the communities recorded between periods give an indication of the degree of change across Broadland, or potentially within river valleys or very large sites. The conclusions gain robustness from the very large data sets involved. The ability to compare surveys of the current types at say 50 year intervals would provide an unequalled opportunity to track changes in the fen resource. If we had had such surveys in 1900 and 1950, we would have a much better and more certain understanding of change than currently.

The ideal surveillance would be a combination of broadscale surveys every 50 years and permanent plots recorded between times. The frequently monitored

permanent plots would provide information about temporal variation in fen vegetation, important in interpreting change implied by data sets separated by decades. Being more frequently recorded, they could provide early warnings of potentially important changes, flagging the need to bring forward the broadscale survey. They might also be located in places of particular fragility or conservation concern whose surveillance monitoring would not be best served by long term periodic and broad scale repeat surveys. The methodology for analysis of the 50-yr survey and for the laying out, recording and analysis of the permanent plots requires further development.

Natural England's condition monitoring could be used to supplement the above surveillance monitoring. Currently, it is too specific in terms of its monitoring outcomes (the condition of particular SSSI features) and the methodology too focused on condition indicators to replace a surveillance programme. A surveillance monitoring scheme needs to encompass all fens, not just SSSI features, and must be able to detect a wide range of change, some of which may not relate to quality. Sensible use of resources suggests that one monitoring scheme should be devised which could be used by Natural England for their condition monitoring. This needs further discussion as NE's condition monitoring is directly related to a statutory duty and cannot therefore be compromised.

Monitoring That Answers Specific and Time-Limited Questions. This kind of monitoring is set up in response to a particular issue or question that requires an answer, for instance *In what ways has the introduction of grazing changed the fen communities on site X? Will the change in flooding regime change the fen communities on site Y?* The geographical area of interest is usually more constrained – focussing on particular sites, compartments, communities or even species - and because the question is specific, the monitoring protocol can be similarly specific. This makes data collection and analysis more efficient and increases the robustness of conclusions drawn. The schemes are usually time limited as once the question is answered, there is no benefit in continuing recording.

Such schemes are usually of interest to site managers considering the effectiveness of management schemes or to regulators concerned about the impact of external activities, such as an abstraction. The fen survey can assist planning of these monitoring schemes by providing the detailed baseline vegetation survey which should be the precursor to laying out the plots.

The two types of monitoring are not incompatible. Surveillance monitoring provides the context for the question-based monitoring. It answers the critical question *Are the changes recorded in the detailed plots attributable to the issues/question being investigated, or are the changes simply part of a broader change being experienced by all fens?* Surveillance, then, provides the control for more specific and local monitoring schemes. Similarly, results of question-based monitoring can help to inform interpretation of broad change by characterising the change in fens arising from specific environmental factors which cause change.

Clearly this survey could form the basis of a comprehensive, Broadland-wide and fully integrated monitoring programme.

8.2 Linking The Fen Survey With Other Data Sets

Some of the key attributes of the fen survey data are:

- Quantitative vegetation data.
- Comprehensive coverage of all of the fen vegetation of Broadland.
- Accurately geo-referenced with 10-digit OS grid reference located by GPS with a resolution of 5m or less.
- Digital presentation and storage of the data, particularly in the GIS format.
- Classification and description of the data within the framework of the NVC.

These attributes lend themselves to linking the fen vegetation survey with the following data sets used to support management of the fen resource:

Hydrological monitoring and modelling data sets. There are a variety of hydrological monitoring schemes which examine both water quantity (dipwells and piezometers, for instance) and water quality (water sampling stations and salinity monitoring, for instance). Some of the monitoring points are relatively new (e.g. those associated with the Review of Consents process), some are old, and others have a patchy history of recording, but all could be brought together and layered with vegetation data in the GIS system.

The fen survey could also be used to identify appropriate hydrological instrumentation networks when undertaking specific site-based investigations or case work. Whether instrumentation should be transect-based or stratified according to vegetation type, could be informed by the vegetation maps.

It should be possible to generate maps of Wetmec types across Broadland using a combination of hydrological data sets and field experience. Linking maps of Wetmecs with the GIS mapping of Broadland vegetation in this survey could greatly enhance our understanding of the fen resource and would have enormous benefits in terms of site management and case work.

Other biodiversity data sets. Linking vegetation data with the invertebrate survey undertaken concurrently with this work is the most obvious example, providing opportunities to correlate plant and animal communities, identify consistent patterns of association and compare botanical and faunal hotspots. It is by no means a given that there will be a coincidence of areas important for plants and invertebrates. Understanding the relationship between plant and invertebrate communities will be important in developing site management proposals and broader conservation strategies. It should also be possible to link vegetation monitoring and that undertaken for invertebrates (Telfer 2010).

There are other biodiversity surveys that would benefit from linking with this data set, including the Broads Dyke Survey and the Broads Wet Woodland Survey. Layering of the different plant communities on the GIS would provide a great deal of information about associations of the various habitat types. Linked to an improved understanding of the kind of fen vegetation that arises from clearance of particular scrub or woodland communities, it would help plan future fen restoration programmes.

Site Management. This is perhaps one of the most critical linkages between data sets. Understanding the link between site management and outcomes in terms of vegetation communities (and other linked biodiversity data sets) *should* inform conservation actions across the spectrum of activity. Analysis of management and vegetation data is useful in evaluating agri-environment schemes, developing individual site restoration and management plans and in constructing strategic resource management initiatives such as the Fen Audit and the Fen Harvester.

Because of the limitations of management data and historical survey information, ELP (2010a) could only draw modest conclusions from their analysis of the impact of management on fen vegetation types. Had site management been adequately documented, it would have been possible to assess the impact of a far wider range of habitat management actions. The challenge now is to encourage accurate, GIS-based management recording among the community of site managers.

Ecological Monitoring. The ability to link the current survey with ecological monitoring data sets has been discussed. In addition to planning botanical monitoring schemes, the vegetation survey will also be important in providing contextual information for invertebrate or other monitoring programmes, including breeding birds. The linking of ecological monitoring data sets will add interpretative value to all.

Understanding the causes of change identified through ecological monitoring data sets requires linking with other environmental data sets. Critical variables include climate data, hydrology and management. Linking all of these data sets together through the GIS platform provides a very powerful tool for analysis and interpretation of environmental change. In addition, the numerical basis for all of the data sets, and their storage in digital databases, facilitates very detailed quantitative and statistical analysis. This greatly increases the utility of monitoring results for evidence-based decision making.

Elevational data. Three sorts of elevation data would benefit from GIS storage and subsequent linking to other data sets:

Land levels. The most obvious data set, this can be acquired rapidly and cost-effectively through LIDAR coverage. LIDAR is not always precise with an error of around +/- 20cm on levels corrected for vegetation cover. This error can be corrected by calibration using traditional levelling methods (see Harding and Smith 2002 for an example of this undertaken in the Brograve catchment). LIDAR data would be extremely valuable in any eco-hydrological modelling on a Broads-wide scale. The wide array of traditional levelling surveys undertaken in the Broads could supplement this data layer.

Ditch bed and water levels. Collected through hydrological casework, there is a wealth of levels data available for watercourses in the Broads, all of which could be useful in informing hydrological assessments of fen compartments.

Groundwater levels. These data are already being collected through EA's groundwater surveillance networks, abstraction boreholes or site monitoring such as Review of Consents or private monitoring schemes. Collation and linkage of these data sets could allow the compilation of two- and three-dimensional groundwater maps for fen

compartments. This could then be linked to topographic and vegetation data sets to provide a more comprehensive understanding of the vegetation of fen compartments. Such combinations would also assist identification and mapping of Wetmechs.

Soils data. Because the substrate is a fundamental abiotic characteristic which strongly influences the nature of the fen resource and its responses to environmental change, linking the fen survey to soil data would be extremely valuable. Of particular importance here is an understanding of the peat resource. In addition to being the most important soil type whose physical and chemical properties strongly influence fen community composition, the fen peat resource has strong links to the management of carbon and to climate change.

The availability of soils data is highly variable in both quality and geographical coverage. There are several extensive data sets available, such as the survey of acid sulphate peats (Broads Authority 1981) and the soil cores and mapping held by the Soil Survey of England and Wales, at Cranfield University. New data is also being collected. For instance, ELP (2010b) undertook sampling of peat soils in 16 sites in the Ant, Bure, Thurne and Waveney catchments as part of a climate change initiative. Core data and peat condition assessments were provided. There is a wealth of other soil data collected for a very wide variety of purposes, both in the public domain and in private notes. They include surveys undertaken for agricultural purposes, development, water resource schemes, flood defence, drilling of boreholes and hydrological monitoring infrastructure, published papers and the private notes of researchers professional and amateur. Even the sides of deep drainage dykes managed by the Internal Drainage Boards offer sometimes deep exposures of local soils that could be readily documented. Collation of these disparate sources would provide an impressive stratigraphical data bank which could be made available for a variety of applications through linked data sets.

Historic Environment Data. It would be of considerable interest to overlay maps of turf ponds, ideally with dates of excavation, onto maps of fen plant communities and the distribution of samples scoring highly in their RWPFSS index. It is probable that there is a strong coincidence between distribution of turf ponds and certain NVC types, and also with the higher RWPFSSs. It might also be valuable to layer other historic environment data and to assess the coincidence of these with fen vegetation types or other attributes.

Once data sets have been linked and displayed via a GIS, it allows resource managers to clearly identify gaps in coverage for important data sets. This is imaginatively termed *gap analysis*. Where several layers are linked and displayed together, gap analysis is particularly effective at identifying areas which are data-rich and areas where paucity of data can seriously hamper planning of conservation or environmental management projects. This can include the planning and management of ecosystem services and strategies for adapting to climate change.

While the benefit of linking any of the data sets described above is clear, the real value will accrue when many or all of these data sets can be linked together. The ability to analyse linked quantitative data sets could greatly inform academic research, the

management of individual sites and the development of resource management strategies.

It is clear that a great deal of the above information is already available and simply needs bringing together in a central location and linking via a GIS system. In so doing, a Broads-wide digital archive of environmental data would be created. Creating this archive would stem the loss of data through poor filing and cataloguing, digital corruption or simple loss that is such a significant issue.

The benefits of linking these data sets will only be realised if the data itself and the GIS system which manipulates it can be made available to the community of users. This requires the data sets to be managed by a public body with an interest in resource management, such as the Broads Authority. Because the ability to interrogate and manipulate the linked data is so central to the work of the Authority, it is natural that they retain and manage the database. The Authority will effectively be acting as stewards for what is a shared resource with very wide applicability.

8.3 Fen Vegetation And Remote Sensing

The term remote sensing here refers to both aerial photographs and more specialist sensors which record particular segments of the electromagnetic spectrum, such as infra-red, microwave and so on. Remote sensing has a very wide range of uses in natural resource management including assessing condition, extent and quality of a particular resource.

The appeal of remote sensing is its ability to rapidly cover large areas of ground. It has clear appeal in the Broads context, where there are very large areas of fen that are often difficult to access. It could be a very cost effective tool in terms of inventory of the resource and surveillance of its condition, both here and in other parts of the country with extensive areas of fen.

The accuracy and reliability of remote sensing for this purpose requires further research. Aerial photographs and those parts of the electromagnetic spectrum which identify crop health are certainly useful for monitoring simple plant communities such as *Calluna* heathlands. They may be useful for monitoring extent and condition of mono-dominant fen communities such as species-poor reed fen or *Cladium* beds. They may be less useful for fen vegetation which is much more complex in terms of structure and composition.

The limitations of aerial photographs in identifying different communities, and in particular the problems associated with the masking effects of a tier of tall helophytes, has been referred to in the *Methods* sections. Segments of the electromagnetic spectrum other than visible light may be better separators of plant assemblages which superficially appear to be similar. The ability of remote sensing to discern indicators of condition may vary according to the criterion of condition chosen and the type of sensor used. Scrub cover is likely to be easy to determine, whereas assessing depth and extent of litter, or the presence and quantity of undesirable species, may be more intractable. .

The significant benefits of remote sensing could bring suggest this is a priority area for research. The current survey could be particularly useful in such research. The high density of very accurately located vegetation samples allows reliable correlations to be made between sensor reflectance values and plant community attributes. The quantitative nature of the vegetation data means that these correlations can be

numeric and their reliability statistically assessed for a variety of vegetation attributes. The latter could include abundance of key species, indices representing particular plant assemblages (perhaps derived from ordination data) or complementary data collected with each sample such as cover of litter or open water.

As far as we know, there is no other data set available which combines accurate geo-referencing, quantitative vegetation data, coverage of a wide range of plant community types, and sheer extent and density of sampling. This makes the data perfect for researching resource management applications of remote sensing.

9. CONCLUSIONS

Over 7000 quantitative and accurately geo-referenced samples, classified according to the national vegetation framework, have been analysed. This report provides a summary of the nature and condition of the fens of Broadland in 2005-9, identifying probable trends and providing a baseline against which to measure future change.

The extraordinary diversity, extent and botanical value represented by the fen resource are described, and the resulting distribution of internationally important habitats has been mapped. The survey demonstrates that the Broads still supports one of the most extensive and diverse suites of fen vegetation types in the UK. These include very species-rich fens, together with a range of plant communities which are rare in the UK and Europe. These include the archetypal Broadland vegetation, S24 *Phragmites australis*-*Peucedanum palustre* tall herb fen. This is the core vegetation type which lies at the intersection of many plant community successions.

A number of new plant communities not recognised by the national scheme have been described in this survey. They include a range of new reed communities, communities dominated by the pond sedges, and a range of fens of eutrophic habitats. The proposed new sub-community of S24, the *Dryopteris cristata*-*Sphagnum* spp mixed mire, is of particular importance for conservation.

Despite the prodigious conservation value of the fens today, there is clear evidence of change, and much of this is negative. There is the loss of the pioneer swamps and the early stages of the hydrosere, and also much of the transition habitat from fen to highland. The decline of management of the fens over at least the last 80 years has led to the replacement of rarer and more species-rich fen types with more widespread and less rich habitats, and to the transition to tall, dense and reed-dominated communities. It has also encouraged the development of scrub and woodland at the expense of high quality fen. Autogenic succession of wet fen types to dry fens or non-fen habitats has degraded the more valuable fen types, including some of the most important turf-pond communities. There is strong evidence of an increase in eutrophic fen vegetation, partly due to the foregoing processes and partly as a result of much wider trends toward eutrophication of the Broads and its catchments. The survey provides evidence, too, of increasing salinity on the ronds and in the fen compartments. In the long term, the Broads fens will have to contend with additional pressure for change arising from shifts in climate.

That the Broads still represents one of the UK's most valuable resources of fens is due largely to the recent investment in restoration and management initiatives. Twenty years ago the fens were in a parlous state. Subsequently, there has been major scrub clearance in the most important fen areas, the development of fen grazing programmes, the introduction of the Fen Harvester to mechanise cutting in some fens, the rejuvenation of the sedge and reed industries, the excavation of shallow turf ponds and a range of individual wetland restoration programmes on private land and nature reserves. This effort, a partnership of national and local conservation organisations, landowners and the reed and sedge cutters, has been an extraordinary success story. The benefits of this partnership are reflected in the results of this survey. If the achievements of the last 20 years are to be sustained, and the fen resource conserved, it is imperative that this effort is maintained.

Although there is a great body of evidence suggesting change in the Broads, corroborated by known changes in key environmental variables, much of the evidence

remains circumstantial. There is an urgent need to set up monitoring programmes which can directly measure future change and inform future management strategies. Further research on a wide range of subjects is required to inform restoration and management of the Broads, and to ensure that future efforts are cost effective. Some priority research areas are identified above. The linking of the vegetation survey to a wide range of other environmental data sets would have very significant benefits to the management of the fen resource. Some of the most important links between data sets are outlined in this report.

Although much has been done to arrest the decline of the fens, more is required to ensure the long term future of the resource. Large areas are still unmanaged, and autogenic change and the accumulation of the peat surface continues. If the fens are to be conserved the following action needs to be undertaken:

- The restoration of the full hydrosere, and in particular the re-establishment of pioneer swamp vegetation at the broad margins.
- The removal of further areas of scrub in areas of critical fen interest and in locations which would restore key parts of the hydrosere.
- Extension of both grazing and cutting to include all of the herbaceous fen resource.
- The continuation of the programme of shallow turf ponding, with the cyclical excavation of peat to a depth of 70cm. This creates some of the most valuable plant communities in Broadland, which do not exist on uncut peat surfaces.
- Ensuring the fen resource is protected against the impacts of climate change. This includes the creation of new fen areas to compensate for the inevitable losses, but also requires research into the precise nature of the likely impacts, and the distribution of such impacts in the Broads. Only then can a strategy for adaptation be fully developed.

Achieving these aspirations will require a step-change in the management of the fens. It calls for a new approach, one which is under-pinned by social and economic sustainability. Habitat management needs to become financially self-sustaining through the identification of new, modern markets for fen produce. The development of composting, which could provide a viable end use for all fen cuttings and the arisings from turf ponding, the development of reed pellets for bio-fuel and other similar products such as biochar and scrub bales, all provide a viable if low-value market for such produce. The technology associated with the cutting, processing and transport of this material has evolved enormously in the last 20 years, and the drive for sustainability now provides the ideal social and political context in which to develop these initiatives.

The development of a new rural industry based on fen produce will require considerable long term investment. It also requires the creation of a new partnership, largely of the same organisations as described above, but broadened to include commercial end-users of and the potential industrial partners who might develop the product. The roles within the partnership might also change. The reed and sedge cutting industry, the last remnant of the workforce that once maintained the fens, could once again be in the vanguard of this new joint enterprise, supported by the array of conservation organisations.

The conclusions presented above are consistent with other initiatives currently being developed by the Broads Authority. These include an investigation into the viability of reed pelleting and composting in the Broads (ELP and Ash 2010), new proposals to support the reed and sedge cutting industry (Broads Authority 2010a) and an outline

for research into assessing hydrological and salinity changes in the Broads fens (Broads Authority 2010b).

If these initiatives are successful, the trends identified through this survey could be reversed, and the full suite of fen vegetation types re-established once again in the Broads. When the fens are re-surveyed fifty years hence, it is hoped that the results might once again demonstrate the full range and richness of the fens originally described by Pallis and Lambert in the last century.

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APPENDIX I: DETAILED DESCRIPTIONS OF THE COMMUNITIES

Units with ten or more samples are described in more detail and summary statistics are included, although some smaller data sets are also described more fully. The data disk attached to this report contains the summary community table for each vegetation type. Where a community is very close to the NVC, description is fairly minimal. Where a community is distinctive, differs significantly from the NVC reference type, or is proposed as a novel community, more comment is made.

A.1 Mires and Fen Meadow

Fen meadow and mire vegetation is extremely variable and supports a suite of species which can be common or even abundant in more than one community. Placing firm boundaries between vegetation types can therefore be difficult, as can assigning individual samples to particular communities. There is a very close relationship between M22 and M24, and to a lesser degree between these two and communities such as MG10, M23 and M25, all of which are present in the Broads data set. There is overlap between fen meadow and the reed fens where management is relaxed, and on wetter low nutrient sites, with M13. The boundaries in the following are therefore quite broad and significant intergradation is expected. Following further character species analysis and consultation with Bryan Wheeler, M9 was reduced to one sample.

M9 *Carex rostrata* – *Calliergonella cuspidata/giganteum* mire

Only one sample was recorded of this vegetation type, from the Bure. The fit with the NVC is not especially good.

M13c *Schoenus nigricans*-*Juncus subnodulosus* mire, *Caltha palustris*-*Galium uliginosum* sub-community.

Stand Metrics

34.2	Mean species number
76.0	Mean height (cm)
13.0	Mean % of open water
2.0	Mean % of bare ground
14.0	Mean % of litter cover
78.0	Mean % bryophyte cover
93.0	Mean % herb cover
22	Total number of samples

Relationship with the NVC

This is a reasonable fit to the NVC type. The community is mostly derived from TWINSpan end-groups 200/201. It has more character species of M13 – mostly more than 10 – than of any other community, and hence has been placed here. Constants normally associated with M24 – *Molinia caerulea*, *Succisa pratensis* and *Potentilla erecta* for instance – are much reduced which shifts the Broadland samples towards the M22 end of the M13 spectrum. Although Broadland is not associated

with these types of vegetation, the survey included valley mire areas where most of the samples were recorded.

Distribution

Other than a few stands in the Ant and Thurne, this community is mostly found in the small tributary valleys. This includes the valley fen sites of Smallburgh Fen and Ducan's Marsh.

M22a *Juncus subnodulosus*-*Cirsium palustre* fen meadow, Typical sub-community

Stand Metrics

Typical	<i>C. nigra</i>	<i>J. effusus</i>	<i>J. acutif</i>	
14.5	17.5	16.1	19.0	Mean species number
71.1	59.1	71.7	72.0	Mean height (cm)
18.4	18.2	37.0	22.0	Mean % of open water
10.7	6.4	4.6	8.0	Mean % of bare ground
72.1	67.7	62.5	80.0	Mean % of litter cover
3.4	1.2	3.3	6.0	Mean % bryophyte cover
96.9	96.8	93.3	100.0	Mean % herb cover
88	11	12	5	Total number of samples

Relationship with the NVC

Four vegetation types have been accommodated within M22a. The first is the large body of samples which fit reasonably well with the reference NVC type, and referred to here as the Typical variant. The other three are newly proposed variants of relatively small but distinctive samples.

The Typical variant is relatively tall, dense and species-poor and is usually strongly dominated by *Juncus subnodulosus*. There are a modest range of associates at high frequency, but the association between this vegetation type and abandonment of management means that this is usually a species-poor fen meadow, and the least rich of the four M22a variants. It shows some transition to tall-herb fens.

The new variants suggest a base-poor influence compared to the Typical variant. They are:

Carex nigra variant – characterised by almost constant and often dominant *C. nigra* with very little *J. subnodulosus*. *J. inflexus* and *Carex disticha*, both characteristic of M22, remain frequent. Other constants typical of M22a are a little lower in frequency while the following are more common: *Galium palustre*, *Mentha aquatica*, *Iris pseudacorus*, *Juncus effusus*, *Juncus inflexus*, *Eupatorium cannabinum*, *Glyceria maxima*, *Equisetum fluviatile*, *Eleocharis palustris*, *Polygonum maculosa*, and *Myosotis scorpioides*. This species group suggests a swamplier, base-poor element to the vegetation. The sub-set of 11 samples was not felt sufficiently different to erect a new sub-community. Whether this variant is a local Broads phenomenon or has more widespread applicability would require further sampling elsewhere.

***Juncus effusus* variant** – The main feature of this sub-set of 12 samples is the constancy and often abundance of *Juncus effusus* and the relative rarity of *J. subnodulosus*. Community constants are again a little reduced but otherwise there are no other positive character species of this community. It is not especially species-poor and does not show any clear relationship to MG10 or M23 (other than the prominence of *J. effusus*) and therefore has been retained within M22a.

***Juncus acutiflorus* variant** – Here, *J. acutiflorus* replaces *J. subnodulosus*. Other community constants are similar to the main group of M22a. This variant is associated with much more frequent *Cardamine pratensis* and *Cerastium fontanum*, and is a little more species-rich than the main sample set.

Distribution

The Bure had most samples, but the community is also well represented in the Thurne and Yare. The Ant and Waveney have many fewer samples.

M22b *Juncus subnodulosus*-*Cirsium palustre* fen meadow, *Briza media*-*Trifolium* spp sub-community

Stand Metrics

26.0	Mean species number
44.7	Mean height (cm)
2.8	Mean % of open water
11.6	Mean % of bare ground
39.1	Mean % of litter cover
32.3	Mean % bryophyte cover
95.7	Mean % herb cover
188	Total number of samples

Relationship with the NVC

The community is a reasonable fit with the NVC reference type. The greater richness of this vegetation compared to the other sub-communities of M22 is reflected in the higher number of constants, although this is still a little lower than the published type. This sub-community has a much greater assemblage of grasses and pasture plants, reflecting the grazing management these swards typically receive. The calcicole element typical of the published community is a little reduced in the current group of samples.

One group of samples is marked by constant and often abundant *Molinia caerulea* and *Cirsium dissectum*, with unusually frequent *Luzula multiflora*, *Carex flacca*, *Succisa pratensis*, *Potentilla erecta*, *Mentha aquatica*, *Centaurea nigra*, *Thalictrum flavum* and *Danthonia decumbens*. This is suggestive of M24 *Molinia caerulea*-*Cirsium dissectum* mire. However, the continued constancy of *Juncus subnodulosus* and many M22 preferentials, and the absence or low frequency of the range of M24 preferentials, suggests the community should remain placed in M22.

Distribution

The community is mostly found in the Yare and Bure, with some samples from the Waveney. The Ant has only a few samples. The samples which may be transitional to M24 are from the Yare.

M22c *Juncus subnodulosus*-*Cirsium palustre* fen meadow, *Carex elata* sub-community

Stand Metrics

18.7	Mean species number
42.5	Mean height (cm)
35.5	Mean % of open water
17.0	Mean % of bare ground
30.0	Mean % of litter cover
18.1	Mean % bryophyte cover
86.0	Mean % herb cover
15	Total number of samples

Relationship with the NVC

This group of samples has a reasonable fit to the NVC reference community, with a good range of the characteristic constant and preferential species. In such a complex and difficult to define set of sub-communities such as those of M22, obtaining a good match between these data sets is likely to be difficult. One potential variant has been identified, where *Juncus subnodulosus* has been replaced by *Carex acutiformis* and *Carex elata* is wholly dominant. The suite of associates typical of M22 is not particularly well represented in this group. As the community clearly does not belong in S1 *Carex elata* swamp or S24 *Phragmites*-*Peucedanum* fen, this group of samples would be a good candidate for a new community were the sample set more numerous.

Distribution

Most of the samples are from the Bure. The variant samples are from the Yare.

M22d *Juncus subnodulosus*-*Cirsium palustre* fen meadow, *Iris pseudacorus* sub-community

Stand Metrics

19.8	Mean species number
72.2	Mean height (cm)
14.4	Mean % of open water
14.0	Mean % of bare ground
60.9	Mean % of litter cover
8.5	Mean % bryophyte cover
94.1	Mean % herb cover
87	Total number of samples

Relationship with the NVC

This is a reasonable fit with the NVC type. It is a large group of samples and rather variable, with a relatively modest number of constants compared to the NVC, reflecting a rather heterogeneous data set. However, the high frequency here of preferentials such as *Iris pseudacorus*, *Carex acutiformis* (which can be dominant in many stands), *Ranunculus flammula*, *Phragmites australis*, *Lysimachia vulgaris* and *Lythrum salicaria* ties the sample set quite well to the M22d sub-community of the NVC. There is a significant overlap with S24 reed fen, with M22d being a community marking the start of a transition to tall herb fen and to vegetation with a clearer “Broadland” stamp.

Distribution

The community was recorded in most river valleys except the Thurne, but was especially common on the Yare and to a lesser extent the Bure.

M23a *Juncus acutiflorus*-*Galium palustre* rush pasture, *Juncus acutiflorus* sub-community

Stand Metrics

17.5	Mean species number
43.5	Mean height (cm)
29.2	Mean % of open water
13.5	Mean % of bare ground
56.5	Mean % of litter cover
7.8	Mean % bryophyte cover
97.3	Mean % herb cover
14	Total number of samples

Relationship with the NVC

The fit with the NVC is good, with all of the community constants and many of the preferentials present in the data set. *Juncus effusus* is reduced with *J. acutiflorus* dominant. Some key species indicating low nutrient conditions, such as *Molinia caerulea* and *Potentilla erecta*, are infrequent or absent. The vegetation is a little poorer in species than the published reference type. In addition there are a number of Broadland and east of England species recorded in these samples but not the NVC – such as *Lysimachia vulgaris*, *Juncus subnodulosus*, *Cirsium dissectum* and *Carex disticha*. Mainly western species are also much reduced. The NVC recorded no samples in the region, M23 being a strongly west of Britain community, so significant differences are to be expected. Overall, then, the vegetation is best placed within M23 but has a distinctly East Anglian feel to it.

Distribution

The samples were nearly all from the Ant and the Bure.

M23b *Juncus acutiflorus*-*Galium palustre* rush pasture,
Juncus effusus sub-community

Stand Metrics

10.3	Mean species number
43.3	Mean height (cm)
0.0	Mean % of open water
19.0	Mean % of bare ground
52.6	Mean % of litter cover
1.3	Mean % bryophyte cover
96.0	Mean % herb cover
44	Total number of samples

Relationship with the NVC

This much poorer vegetation is mostly dominated by *Juncus effusus* (although in some stands the rush can be sparse) and has a relatively undistinguished flora. It is placed with M23 rather than MG10 because of the frequency and abundance of *Agrostis canina*, *Potentilla erecta*, *Hydrocotyle vulgaris* and *Carex panicea*. Some of the samples with abundant *Juncus subnodulosus* are clearly transitional to M22 but do not have the suite of associates typical of this NVC unit. Such samples are better retained here. There is if anything a greater representation of East Anglian fen specialities and lack of west of Britain species, and comments made regarding M23a are equally relevant here.

Distribution

This community is almost exclusively from the Thurne with just two samples from the Ant.

M24a *Molinia caerulea*-*Cirsium dissectum* mire,
Eupatorium cannabinum sub-community.

Stand Metrics

25.4	Mean species number
58.5	Mean height (cm)
6.9	Mean % of open water
11.2	Mean % of bare ground
44.6	Mean % of litter cover
26.9	Mean % bryophyte cover
95.4	Mean % herb cover
14	Total number of samples

Relationship with the NVC

This vegetation has a reasonable fit with the reference NVC community. Many of the key constants are present although are reduced in frequency and some, such as *Cirsium dissectum*, very under-represented. *Juncus subnodulosus* is constant and often

abundant and although this species is a typical component of M24a, its abundance and the poor representation of M24 indicator species suggests transition to M22.

There is a range of rare fen species and those indicating wet conditions. In two samples *Carex diandra* was prominent, suggesting transition toward M9. However, there were insufficient character species of M9 and the samples have been retained here. Although not the richest of the M24 vegetation, it is an important community for conservation.

Distribution

The community is recorded from fen meadows in the Bure and Yare.

M24b *Molinia caerulea*-*Cirsium dissectum* mire, Typical sub-community.

Stand Metrics

26.2	Mean species number
33.6	Mean height (cm)
1.4	Mean % of open water
12.5	Mean % of bare ground
31.8	Mean % of litter cover
37.1	Mean % bryophyte cover
95.5	Mean % herb cover
30	Total number of samples

Relationship with the NVC

There is a reasonable match between the vegetation and the reference NVC type, with good representation of constants and preferentials of M24b, and a reasonable count of M24 “character species”. In terms of the TWINSpan analysis, this is a relatively coherent set of samples. The Typical sub-community is weakly defined in the NVC, mostly by reduced frequency or absence of the preferentials which define the other two sub-communities. However, the Broads samples gathered together here most closely match with M24b.

Juncus subnodulosus is frequent and can be dominant suggesting transition to M22. However, considering the general difficulty of this kind of fen meadow vegetation, the separation of this stand with other mire types is relatively good.

Distribution

Most of the samples are from the Yare, some from the Bure and a few from the Ant.

M24c *Molinia caerulea-Cirsium dissectum* mire,
Juncus acutiflorus-Erica tetralix sub-community.

Only three samples were assigned to this community, with a mean species number per quadrat of 23.3. The fit to the NVC is reasonable and there is no clear alternative to M24c. The community contains rich-fen, poor fen and wet heath species in what some have termed mixed mire. It has some affinity to M25 *Molinia caerulea-Potentilla erecta* mire, but has a much stronger representation of calcareous mire and east of England species. Further sampling would help place this very rare community with more confidence.

M25b *Molinia caerulea-Potentilla erecta* mire,
Anthoxanthum odoratum sub-community

Stand Metrics

17.6	Mean species number
36.8	Mean height (cm)
0.0	Mean % of open water
31.2	Mean % of bare ground
22.4	Mean % of litter cover
31.0	Mean % bryophyte cover
87.4	Mean % herb cover
19	Total number of samples

Relationship with the NVC

This is a reasonable fit to the NVC although *Molinia* is a little reduced in the Broadlands, and for the sub-community, *Juncus effusus* more frequent and abundant than the reference vegetation.

This is generally a grassy community with reduced frequency of some of the M25 herbs. Atypical in the Broadland samples is the range of poor-fen species, in particular the *Sphagna* and other poor-fen bryophytes. There is some transition at least in some samples to M25a, the *Erica tetralix* sub-community.

Distribution

Most of the samples were from the Thurne, but there were also samples from the Yare, Waveney and Ant catchments.

A.2 Mesotrophic Tall Herb Fen and Swamps

This section encompasses the majority of the samples and the majority, too, of newly proposed communities. Most of the new communities are related to S4 species-poor reedbeds, *Carex* swamps and *Calamagrostis* fen, none of which are dealt with adequately in the NVC. The *Dryopteris cristata-Sphagnum* spp. fen is proposed as a new sub-community of S24.

S1 *Carex elata* sedge-swamp

11	Mean number of species
60	Herb height (cm)
40	Open water (%)
30	Bare ground (%)
30	Litter cover (%)
10	Bryophyte cover (%)
70	Herb cover (%)
3	Total no. of samples

Three samples from this community marked by overwhelming dominance of *C. elata*.

**S2a *Cladium mariscus* swamp,
Cladium mariscus sub-community**

Stand Metrics

3.4	Mean species number
163.6	Mean height (cm)
33.0	Mean % of open water
6.1	Mean % of bare ground
82.4	Mean % of litter cover
0.0	Mean % bryophyte cover
96.6	Mean % herb cover
144	Total number of samples

Relationship with the NVC

Fit with the NVC reference community is good. The stand is dominated by *Cladium*, although always with varying quantities of reed which is not typical of the reference type. Pure or nearly pure stands of sedge were very rare during the sampling of the Broads fens. Although constant reed would normally place the community in the *Menyanthes trifoliata* sub-community, the range of aquatic and semi-aquatic fen plants typical of S2b are mostly absent. This, combined with the species-poverty of the stand together with the presence of the preferential *Solanum dulcamara*, places the vegetation in S2a.

Distribution

The largest stands and the vast majority of samples come from the Thurne, particularly the Martham-Hickling-Horsey Broads. These by repute may be some of the largest stands of *Cladium* in Western Europe. There are a small number of samples from the Ant catchment.

Intermediate :

- S2b** *Cladium mariscus* sedge-swamp,
 Menyanthes trifoliata sub-community and
S25c *Phragmites australis*-*Eupatorium cannabinum* fen,
 Cladium mariscus sub-community

Stand Metrics

8.0	Mean species number
151.4	Mean height (cm)
28.3	Mean % of open water
6.3	Mean % of bare ground
81.7	Mean % of litter cover
0.9	Mean % bryophyte cover
95.9	Mean % herb cover
209	Total number of samples

Relationship with the NVC

This vegetation includes a substantial proportion of stands commercially cut for sedge. *Cladium* and *Phragmites* are both constant with *Cladium* most often dominant. The Broads samples fall between the two NVC reference communities, lacking *Menyanthes* and a number of the low frequency preferentials of S2b, but having high cover and frequency of *Juncus subnodulosus* which is typical of S25c. It lacks *Eupatorium* at high frequency and is depleted in terms of the species-richness typical of S25c. Hence it has been placed as an intermediate. Even the reference S2b and S25b NVC types are floristically close to each other, and share a number of associates at moderate frequency in an otherwise species-poor vegetation.

A group of samples includes a range of aquatic species including *Chara* spp., bryophytes and *Potamogetons*, (and in some samples, *Schoenus nigricans*) indicating shallow pool habitats, but these species are generally infrequent in the community.

Distribution

This is principally a vegetation type of the Thurne, with a number of stands in the Ant and a handful from the Bure.

- S4a** *Phragmites australis* swamp, Typical sub-community

New Variants of S4a

The large body of very species-poor reed communities which classifies as S4a includes a number of stands where there is dominant reed with one other constant species which is often abundant. Other associates are usually very few, generally infrequent and not abundant. Because of the abundance and constancy of the single main associate, which gives these vegetation types a very distinctive character, they have been assigned as new variants of S4a. They do not have a greater floristic development to rank them as new sub-communities. Some have analogue variants in other sub-communities of S4.

Cladium mariscus variant

Stand Metrics

3.8	Mean species number
182.3	Mean height (cm)
28.7	Mean % of open water
9.8	Mean % of bare ground
81.2	Mean % of litter cover
0.4	Mean % bryophyte cover
97.8	Mean % herb cover
51	Total number of samples

Relationship with the NVC

The community is placed in S4a because of its constancy and overwhelming dominance by reed, and its great species-poverty.

However, the NVC does not recognise a species-poor reed over *Cladium* community. This new variant recognises an S4a which has a lower tier of *Cladium* which is very much subordinate to reed in abundance and has therefore been rejected from S2.

There are few other species associated with the community – some *Juncus subnodulosus*, and climbers and sprawlers. In wetter situations there is a modest component of aquatic and semi-aquatic species, but considering the number of samples represented here, the associated list of species is modest.

Distribution

This is almost exclusively a community from the Thurne, with just a few samples from the Ant.

Solanum dulcamara variant

Stand Metrics

3.4	Mean species number
194.1	Mean height (cm)
19.3	Mean % of open water
11.3	Mean % of bare ground
70.6	Mean % of litter cover
0.2	Mean % bryophyte cover
99.2	Mean % herb cover
373	Total number of samples

Relationship with the NVC

This is a poor fit to S4a, with *Solanum dulcamara*, *Calystegia sepium*, *Carex riparia* and *Carex acutiformis* much more frequent than the published community, and generally

more abundant. Because of these marked differences and the very large data set, the group has been proposed as a new variant. There is a very wide range of species at very low frequency, reflecting the large size of the data set. The community includes a number of non-fen species or those of contact communities. The non-native *Impatiens capensis* is probably an increasing feature of this vegetation. The flora suggests neutral and base-poor conditions. Although high water tables characterise the samples, the mean % cover of open water is less than the *Cladium* variant.

Distribution

This reed vegetation can be found throughout the five valleys but is particularly marked in the Thurne and the Yare. Pure stands can be extensive in the former, whereas in the Yare it is often in mosaic with other species-poor tall fen types.

Lemna spp variant

Stand Metrics

3.5	Mean species number
223.3	Mean height (cm)
68.3	Mean % of open water
15.5	Mean % of bare ground
70.9	Mean % of litter cover
0.1	Mean % bryophyte cover
99.6	Mean % herb cover
95	Total number of samples

Relationship with the NVC

Here *Lemna minor* is constant and often abundant over water or wet ground, and very distinctive. There is a greater representation of water margin, semi-aquatic and aquatic species, although all remain very infrequent under a very dense reed canopy. The proportion of open water is one of the highest of all communities. As a consequence of the increased wetness, there is a commensurate decrease in some of the species which mark the previous variant, such as *Solanum*, *Calystegia sepium* and the non-fen species and indicators of contact communities.

Distribution

The community was found in the Bure, Ant, Thurne and Yare. It was sometimes associated with engineering works on nature reserves to create wet reedbed, and around the margins of scrapes and turf ponds.

Agrostis stolonifera variant

Stand Metrics

4.2	Mean species number
137.1	Mean height (cm)
8.2	Mean % of open water
38.2	Mean % of bare ground
39.8	Mean % of litter cover
1.3	Mean % bryophyte cover
95.8	Mean % herb cover
116	Total number of samples

Relationship with the NVC

The samples gathered here have the rather indistinct flora associated with S4a, except constant and often abundant *Agrostis stolonifera*, hence the assignment of a specific variant. The community is highly distinctive in the field, often consisting of a mat of *Agrostis* with a sometimes sparse tier of reed above. There is often a swampy element to the vegetation, and equally distinctive, species indicating mildly brackish conditions. This community has not been placed in S4b because it does not have the range of preferentials at high frequency which marks out that sub-community. In particular, *Galium palustre* is at much reduced frequency.

The community is often found in a zone adjacent to leaky river walls where brackish river water has influenced the fen. Wheeler (in litt., 2010) also suggests that the community may develop over exposures of saline marine clays, whether or not they are close to leaky walls. According to Rick Southwood, these clays may be exposed when sourcing material for repairing river walls.

The community may be transitional to the brackish water reedbeds assembled under S4d, the *Atriplex prostrata* sub-community. Although S4d also has an *Agrostis stolonifera* variant, it is much more saline in character. A new *Agrostis stolonifera* variant of S4b is also proposed below. Clearly, *A. stolonifera* has a running theme through the several of the sub-communities of S4.

Distribution

The community is present in the middle and lower courses of the Waveney, Bure, Thurne and Yare, generally on the inside of the river walls within the fen compartments. It is more or less absent from the Ant and from the upper reaches of the other rivers.

S4b ***Phragmites australis* swamp,
Galium palustre sub-community.**
 Typical variant
 ***Agrostis stolonifera* variant**

Stand Metrics

Typical	Ag Stol	
6.6	8.6	Mean species number
194.4	162.0	Mean height (cm)
21.7	23.3	Mean % of open water
13.6	22.4	Mean % of bare ground
65.5	52.5	Mean % of litter cover
3.1	5.1	Mean % bryophyte cover
99.3	97.7	Mean % herb cover
319	142	Total number of samples

Relationship with the NVC

This large data set of 451 samples has been divided into two variants; the typical one which matches well the S4b NVC reference type, and the newly proposed *Agrostis stolonifera* variant.

The new variant is distinctive in having constant and often abundant *Agrostis stolonifera* forming a ground layer. Other features of the variant are higher than normal frequency of *Berula erecta*, *Thelypteris palustris*, *Typha angustifolia*, *Rumex hydrolapathum* and *Cardamine pratensis*, but rather less *Lemna minor* and *Solanum dulcamara*. However, it is the *Agrostis stolonifera* that really marks out this set of samples from the typical S4b fens. In this it is analogous to the more species-poor *Agrostis stolonifera* variant of S4a. Both the current *Agrostis stolonifera* variant of S4b, and that of S4a, were felt to be closer to their host sub-community than to each other and therefore retained in those vegetation types as variants.

Distribution

Both variants are found throughout the Broads area, with the *Agrostis stolonifera* variant perhaps a little more frequent in the Thurne.

S4d ***Phragmites australis* swamp
Atriplex prostrata sub-community,**

Stand Metrics

3.7	Mean species number
132.3	Mean height (cm)
7.8	Mean % of open water
33.7	Mean % of bare ground
55.8	Mean % of litter cover
0.0	Mean % bryophyte cover
99.2	Mean % herb cover
92	Total number of samples

Relationship with the NVC

S4d includes *Phragmites australis* swamps with a significant saline flora element typical of the upper to mid saltmarsh (Rodwell 1995). This very species-poor vegetation appears to be a reasonable fit to the reference NVC type. Reed is dominant over a tier of sparse low growing associates among which upper salt marsh species are frequent. Other freshwater fen species are much reduced, providing a very clear separation from the previous S4 sub-communities. There is no clear affinity with any of the S4d variants.

Distribution

The community is predominantly located on the ronds of the lower River Yare, with a few samples in the lower Thurne and Waveney. It is absent from the Bure and Ant.

- S4d** ***Phragmites australis* swamp,**
 ***Atriplex prostrata* sub-community**
 S4dii *Puccinellia maritima* variant
 S4diii *Agrostis stolonifera* variant

Stand Metrics

SD4ii	SD4iii	
7.3	8.9	Mean species number
133.8	91.4	Mean height (cm)
15.2	31.1	Mean % of open water
25.8	33.2	Mean % of bare ground
58.3	62.8	Mean % of litter cover
0.0	0.1	Mean % bryophyte cover
98.7	90.4	Mean % herb cover
26	28	Total number of samples

Relationship with the NVC

The NVC partitions the sub-community into three variants of which two were recorded in the current data set:

S4dii *Puccinellia maritima* variant

The fit of the Broads samples is reasonable. *Atriplex* is frequent rather than constant. There is a range of other frequent species, including *Aster tripolium*. Overall species-richness is reasonable. However, *Puccinellia maritima* is rather rare compared to the reference type. In some samples presumably with less saline influence, the fen element can be more prominent.

S4diii *Agrostis stolonifera* variant

The community is a good fit to the NVC type, although *Juncus gerardii* is a little less frequent than in the reference community, and *Aster* rather more frequent.

Distribution

This is a community of the Waveney and Yare ronds, with a couple of S4diii samples from the Thurne.

S4 *Phragmites australis* swamp,

Proposed new sub-communities

The sample groups presented here are too species-rich to be accommodated by the S4a *Phragmites australis* sub-community or its newly proposed variants. However, they are highly distinctive and consist of significant numbers of samples. *Galium palustre* is mostly very infrequent and therefore the samples cannot be placed with S4b, even as specific variants. They have been derived from a reasonably coherent TWINSpan analysis, mostly end-group 180 with the *Calamagrostis* sub-community being almost all end-group 177. Subsequently they have been derived from hand-sorting of the residual groups of samples.

BS(e) *Utricularia vulgaris*-*Potamogeton coloratus*-*Hydrocharis morsus-ranae* sub-community

Stand Metrics

8.1	Mean species number
185.3	Mean height (cm)
83.6	Mean % of open water
36.2	Mean % of bare ground
36.2	Mean % of litter cover
4.2	Mean % bryophyte cover
94.1	Mean % herb cover
17	Total number of samples

Relationship with the NYC

This is a small but highly distinctive group of samples. These are the wettest stands of the new S4 sub-communities, whose ground layer is characterised by aquatic and semi-aquatic plants. *Phragmites* remains mono-dominant above the ground layer throughout, placing the vegetation firmly in S4, with both species of *Typha* present at low frequency.

The most characteristic associates of the community are the aquatic species which may be patchily abundant in the ground layer, especially in shallow pools. In addition to the species which name the community, *Lemna minor* and *Chara* species (especially *C. globularis*) are frequent, and there are less frequent records for *Drepanocladus* moss species, *Utricularia minor*, *Hippuris vulgaris*, *Lemna trisulca*, *Myriophyllum spicatum* and the rare *Najas marina* recorded in the Thurne catchment.

Water margin plants such as *Berula erecta* and *Alisma plantago-aquatica* also feature. Species of wet, base-rich fens are also patchy in the lower tier, most notably *Juncus subnodulosus* and *Carex elata*, but many of the fen species associated with wetter types of S24 are present albeit at low frequency. Although this is essentially a

species-poor swamp community, it has some clear affinities to tall herb fens. The community also has a distinctly base-rich and calcareous aspect. Drier fen species are mostly absent.

Distribution

The community was recorded from the Ant and the Bure with two samples from the Thurne.

BS(f) *Carex acutiformis* sub-community

Stand Metrics

8.7	Mean species number
176.5	Mean height (cm)
77.5	Mean % of open water
23.8	Mean % of bare ground
58.8	Mean % of litter cover
0.9	Mean % bryophyte cover
95.9	Mean % herb cover
17	Total number of samples

Relationship with the NVC

This new sub-community again fits within the compass of S4 due to the constancy and single dominance of reed, but is distinctive because of the constant and in places abundant *Carex acutiformis*. Other associates below the reed include *Mentha aquatica*, *Galium palustre*, *Lycopus europaeus*, *Carex riparia*, *J. subnodulosus*, *Filipendula ulmaria*, *Lythrum salicaria*, *Solanum dulcamara*, and on the wet ground, *Lemna minor*. Although still a wet reed fen community, it lacks the marked aquatic flora of the previous sub-community and has a flora more closely associated with slightly drier and more fertile tall herb fens.

Distribution

Most of the samples are from the Ant and some from the Bure, with a few from other catchments.

BS(g) *Lemna minor* sub-community

Stand Metrics

7.9	Mean species number
201.7	Mean height (cm)
57.6	Mean % of open water
14.0	Mean % of bare ground
63.7	Mean % of litter cover
6.4	Mean % bryophyte cover
97.6	Mean % herb cover
39	Total number of samples

Relationship with the NVC

Being relatively species-poor and strongly dominated by reed, the vegetation is clearly placed within S4. Constant and often dominating the ground layer is *Lemna minor*, often with other *Lemna* spp. especially where the reed canopy is a little more open. *Solanum dulcamara* and *Typha latifolia* are the other frequent constituents of the vegetation, although they never attain high cover.

At much lower frequency, there is *Carex acutiformis*, *Lythrum salicaria*, *Peucedanum palustre* and *Berula erecta*. Otherwise there is a scattering of wet fen and swamp species, and rarely some semi-aquatic species. It is less rich than the first two sub-communities.

Clearly analogous to the *Lemna* variant of S4a, this new sub-community is considered too species-rich and distinctive to be amalgamated with this unit.

Distribution

The stand is primarily associated with the Ant. There were a couple of samples each from the Bure, Thurne and Yare.

BS(h) *Solanum dulcamara*-*Calystegia sepium* sub-community

Stand Metrics

6.9	Mean species number
195.4	Mean height (cm)
16.4	Mean % of open water
12.1	Mean % of bare ground
76.1	Mean % of litter cover
0.4	Mean % bryophyte cover
99.6	Mean % herb cover
14	Total number of samples

Relationship with the NVC

This proposed new sub-community is at the drier end of the S4 spectrum, and is the poorest in species of all the new S4 sub-communities. Along with *Solanum* and *Calystegia*, the stand is distinguished by infrequent *Calamagrostis canescens*, *Typha angustifolia* and *Carex acutiformis*. Most other species are rarely recorded. Most indicate low water tables, although one sample recorded aquatic plants. Bryophytes are very rare.

It is analogous to the new *Solanum dulcamara* variant of S4a, but significantly richer and more distinctive.

Distribution

The community was found mostly in the Ant and Bure catchments.

BS(i) *Calamagrostis canescens* sub-community

Stand Metrics

7.3	Mean species number
160.3	Mean height (cm)
15.8	Mean % of open water
5.8	Mean % of bare ground
73.3	Mean % of litter cover
3.7	Mean % bryophyte cover
98.3	Mean % herb cover
18	Total number of samples

Relationship with the NVC

This community is distinctive in the constant and often abundant *Calamagrostis* underneath a variable tier of reed.

It is at the distinctly dry end of the range of new S4 sub-communities with *Solanum dulcamara*, *Eupatorium cannabinum*, *Calystegia sepium*, *Juncus effusus*, *J. subnodulosus*, *Carex riparia* and *Peucedanum palustre* being particularly characteristic if mostly infrequent. There is a long tail of rare herbs and bryophytes which are generally indicative of low water tables.

Distribution

This vegetation type was recorded mostly from the Thurne and from the Ant.

Intermediate:

- S4d** *Phragmites australis* swamp,
 Atriplex prostrata sub-community
SM24 *Elytrigia atherica* saltmarsh community

Stand Metrics

3.0	Mean species number
119.7	Mean height (cm)
0.0	Mean % of open water
12.1	Mean % of bare ground
82.9	Mean % of litter cover
0.0	Mean % bryophyte cover
100.0	Mean % herb cover
20	Total number of samples

Relationship with the NVC

Abundant *Elytrigia* under a variable canopy of reed marks out this community. Where the reed is dense the stand tends toward S4d in character, where the reed is thinner with a greater range of halophytes, the stand tends toward a true SM24 high saltmarsh community, but overall it is intermediate.

Distribution

Typically this is a rond community on the lower River Yare.

Intermediate between:

- S4b** *Phragmites australis* swamp,
 Galium palustre sub-community
S13 *Typha angustifolia* swamp

Stand Metrics

7.5	Mean species number
180.0	Mean height (cm)
54.1	Mean % of open water
23.1	Mean % of bare ground
62.9	Mean % of litter cover
6.6	Mean % bryophyte cover
95.6	Mean % herb cover
26	Total number of samples

Relationship with the NVC

This community lies between the two nominated NVC types, particularly in respect of co-dominance of *Phragmites* and *Typha*. It may perhaps lie closer to S4b than S13, especially if the *Agrostis stolonifera* variant is considered which also has *Typha*. However, for now it has been retained as a transitional community.

Distribution

The community has been almost entirely recorded in the Thurne.

- BS1** *Phragmites australis-Carex riparia* swamp

Stand Metrics

7.0	Mean species number
183.9	Mean height (cm)
6.7	Mean % of open water
6.2	Mean % of bare ground
78.6	Mean % of litter cover
1.2	Mean % bryophyte cover
98.9	Mean % herb cover
61	Total number of samples

Relationship with the NVC

This species-poor vegetation type is mostly dominated by *Phragmites*, but dominance can switch sometimes to *Carex riparia*, the other main community constant. Other species at high frequency are *Solanum dulcamara* and *Calystegia sepium*. *Iris pseudacorus*, *Phalaris arundinacea* and *Eupatorium cannabinum* are also distinctive. The more frequent species suggest slightly drier and perhaps more fertile substrates than the foregoing swamps. No other species are frequent, although some may be abundant in particular stands of what is a rather patchy vegetation type. There is a long tail of species, the great majority of which are present at less than 10% frequency and around half less than 5%. These rare associates do not indicate a consistent set of habitat characteristics.

This community has been proposed as a new community, outside of the NVC, because:

- The TWINSpan analysis provided a relatively coherent end group.
- Floristically it is distinctive. The combination of reed, *Carex riparia* and the two climbers at constancy is not represented in other NVC types and does not reflect a transitional community between S4 and S6, or even S25.
- The associated species have no similarity to any of the eight under-storey assemblages used by Rodwell (1995) to separate tall herb fen communities, while the vegetation is too complex to be assigned to a swamp community.
- The sample group is quite large and the unit is replicated in a wide range of sites. It is readily recognisable in the field.

Whether this is recognised at the national scale or retained as a local community requires further sampling and analysis outside of the Broads data set.

Distribution

This is essentially a community from the Thurne and to a lesser extent, the Yare.

S5 *Glyceria maxima* swamp, no assigned sub-community.

Stand Metrics

9.5	Mean species number
118.7	Mean height (cm)
28.9	Mean % of open water
11.5	Mean % of bare ground
77.4	Mean % of litter cover
0.0	Mean % bryophyte cover
96.7	Mean % herb cover
24	Total number of samples

Relationship with the NVC

S5 is the best fit to the NVC for this group of samples, but it is not an especially good one. The community has the constancy and dominance of *Glyceria* as does S5, but there is a range of frequent species – reed especially – which does not feature in the NVC reference type. Overall, the community is richer than for instance S5a,

but does not have the range of associates which characterise S5b. There is some affinity to the *Glyceria maxima* sub-community of S24, but the group is not nearly species-rich enough to be placed here and does not have the range of tall herb associates typical of this unit. This group of samples has therefore been placed in S5 without assigning a sub-community.

Distribution

Other than a few from the Bure, all of the samples are from the Yare.

S5a *Glyceria maxima* swamp, *Glyceria maxima* sub-community

Stand Metrics

4.1	Mean species number
142.3	Mean height (cm)
10.8	Mean % of open water
10.5	Mean % of bare ground
71.5	Mean % of litter cover
1.1	Mean % bryophyte cover
98.3	Mean % herb cover
20	Total number of samples

Relationship with the NVC

The vegetation is not a close match to S5a, but it is the best location for this small set of samples. It is strongly dominated by *Glyceria* and is very species-poor, hence its placement here. However, the high frequency of reed (usually at low cover) is atypical, and the associates at a frequency of 40% or more, such as they are, are different to the two that are listed in the published NVC tables. However, bearing in mind the overall species-poverty of the vegetation, this remains the best placement of the samples. There is certainly no justification for identification of a new unit.

Distribution

This is mostly a Yare community, although it is present in the Waveney. There is a couple of samples from the Bure and one from the Ant.

S5b *Glyceria maxima* swamp, *Alisma plantago-aquatica*-*Sparganium erectum* sub-community

Two samples only were recorded from this community, with nine species per sample.

Indeterminate: *Glyceria maxima* fen

Stand Metrics

14.5	Mean species number
73.8	Mean height (cm)
30.0	Mean % of open water
27.5	Mean % of bare ground
52.5	Mean % of litter cover
1.3	Mean % bryophyte cover
91.9	Mean % herb cover
8	Total number of samples

Relationship with the NVC

This group of eight samples does not fit the NVC and has been left indeterminate. It is dominated by *Glyceria maxima* but has no close affinity to any of its reference NVC communities.

S6(1) *Carex riparia* swamp

Stand Metrics

4.4	Mean species number
152.6	Mean height (cm)
20.7	Mean % of open water
2.4	Mean % of bare ground
80.6	Mean % of litter cover
0.0	Mean % bryophyte cover
98.8	Mean % herb cover
17	Total number of samples

Relationship with the NVC

The community provides a reasonable fit with the NVC reference type, the latter having substantially more samples to draw upon than this survey. The Broadlands samples have more frequent reed and perhaps fewer fen associates, although species number per sample is similar. The current samples may also have a slightly higher representation of species indicating eutrophic conditions which may reflect the Yare context of most samples. Otherwise, the community is not distinctive to Broadland. The samples have been separated from the much richer and rather different samples gathered together below as S6(2).

Distribution

Most samples are from the Yare, with some from the Waveney and a few from the Bure. One was from the Ant catchment.

S6(2) *Carex riparia* swamp

Stand Metrics

10.5	Mean species number
85.5	Mean height (cm)
24.5	Mean % of open water
12.7	Mean % of bare ground
78.2	Mean % of litter cover
0.4	Mean % bryophyte cover
98.6	Mean % herb cover
11	Total number of samples

Relationship with the NVC

The dominance of *Carex riparia* clearly places this community in S6 but the fit is not especially good in that the vegetation is much richer here than in the NVC with a much greater range of associates at high frequency, including the ubiquitous reed. The flora is not sufficiently well defined to be assigned as an intermediary with another NVC unit. It has therefore been retained and will be mapped as S6 but is clearly different from the foregoing S6 community.

Both this and the foregoing S6 are quite distinct from the newly proposed *Phragmites-Carex riparia* community described above. Reed in the two stands of S6 is much lower in frequency and is markedly subordinate in cover. The stands have wholly different preferentials.

Distribution

Small numbers of samples were recorded from the Ant, Yare, Thurne and Bure.

S7 *Carex acutiformis* swamp

Stand Metrics

6.0	Mean species number
127.9	Mean height (cm)
27.8	Mean % of open water
9.4	Mean % of bare ground
104.6	Mean % of litter cover
0.1	Mean % bryophyte cover
99.6	Mean % herb cover
25	Total number of samples

Relationship with the NVC

The dominance of *Carex acutiformis* clearly places this community in S7, but as with the above S6, the fit is not especially good. The vegetation is more species-rich and with some differences in the range of frequent associates compared to the reference community.

Distribution

The community was particularly associated with the Yare but the Bure and Ant also recorded samples.

Intermediate:

S6 *Carex riparia*

S7 *Carex acutiformis* swamps

Stand Metrics

5.8	Mean species number
117.9	Mean height (cm)
8.5	Mean % of open water
1.4	Mean % of bare ground
96.4	Mean % of litter cover
0.0	Mean % bryophyte cover
96.7	Mean % herb cover
47	Total number of samples

Relationship with the NVC

The community is not a straightforward fit with the NVC and has been placed as intermediate between S6 and S7 because of the constancy of both the sedges, where either may be dominant or they may co-dominate. Also prominent are tall fen herbs such as *Eupatorium cannabinum*, *Iris pseudacorus*, and *Persicaria maculosa*. Indicators of more eutrophic fens are present, with infrequent *Urtica dioica*, but this is not a marked feature of the vegetation. The associates of the samples in the current survey are not closely aligned with the associates of the reference NVC communities. There is also no strong correlation between one dominant sedge and a particular group of associates.

The data set includes very species-poor samples which did not enter the Twinspan analysis.

Distribution

Other than four from the Bure, samples were exclusively from the River Yare.

BS2 *Carex acutiformis*-*Filipendula ulmaria* fen

Stand Metrics

10.2	Mean species number
115.4	Mean height (cm)
26.8	Mean % of open water
4.2	Mean % of bare ground
90.3	Mean % of litter cover
0.1	Mean % bryophyte cover
97.6	Mean % herb cover
84	Total number of samples

Relationship with the NVC

This community did not fit within the NVC. It has a much wider range of quite different associates (and at high frequency) compared to S7 *Carex acutiformis* swamp (which Rodwell (1995) defined with only 5 samples), and there is more of a tall herb and eutrophic fen stamp to the Broads vegetation. It does not fit adequately within OV26c *Epilobium hirsutum* community, and is not sufficiently eutrophic or ruderalised for S26 *Phragmites-Urtica* swamp. The range of associates did not fit with any of Rodwell's four groups of fen associates.

Carex acutiformis and *Filipendula ulmaria* are the sole constants. The sedge dominates nearly all stands, although it can rarely be sub-dominant to tall helophytes such as *Glyceria*, *Phragmites*, and *Phalaris*. The first is occasional but the other two are generally infrequent and the vegetation can be quite patchy. *Mentha aquatica* and *Equisetum palustre* are both frequent but never abundant, and there are a range of infrequent associates often drawn from drier or more fertile fens. These include *Urtica*, *Galium aparine*, *Epilobium hirsutum*, *Persicaria maculosa*. Otherwise, there is a wide range of fen meadow and tall herb fen species at frequencies of 10% or less. Wet fen species are generally very rare.

Although species of eutrophic fens are reduced compared to S26 and OV26 communities, their noticeable presence gives a moderately eutrophic feel to the vegetation.

Distribution

The community is most common in the Bure and to a lesser extent the Yare with a handful of samples in the Waveney.

S8 *Schoenoplectus lacustris* swamp

Stand Metrics

8.5	Mean species number
181.0	Mean height (cm)
25.0	Mean % of open water
42.0	Mean % of bare ground
42.0	Mean % of litter cover
0.2	Mean % bryophyte cover
77.0	Mean % herb cover
15	Total number of samples

Relationship with the NVC

In the constancy and dominance of *Schoenoplectus*, the stand falls clearly within S8, but is somewhere between the two sub-communities and has a range of associates that are all more frequent and abundant than the NVC reference sub-community accounts would suggest. The fit is therefore not especially close and the vegetation is clearly transitional to one of the S4 reed swamp communities.

S9 *Carex rostrata* swamp

There are two samples from this species-poor community, both from the Ant catchment.

S12b *Typha latifolia* swamp,
Mentha aquatica sub-community

Stand Metrics

8.1	Mean species number
153.4	Mean height (cm)
87.1	Mean % of open water
42.0	Mean % of bare ground
34.6	Mean % of litter cover
0.2	Mean % bryophyte cover
91.1	Mean % herb cover
28	Total number of samples

Relationship with the NVC

The fit with the NVC reference type is reasonable, although the range of associates is a little different in the current sample group. In addition, this vegetation is perhaps less overwhelmingly dominated by *Typha* than in the typical S12, and has many more frequent associates. Both factors may reflect the Broads fen context within which these samples are situated.

Distribution

It is almost exclusively recorded from the Ant catchment, with only four other samples, from the Yare.

S12c *Typha latifolia* swamp,
Alisma plantago-aquatica sub-community

Stand Metrics

13.0	Total no. of species:
133.3	Herb height (cm)
50.0	Open water (%)
28.3	Bare ground (%)
56.7	Litter cover (%)
0.0	Bryophyte cover (%)
82.5	Herb cover (%)
6	No. samples

Six samples from the Ant catchment make up this community. The fit with NVC is reasonable.

S13 *Typha angustifolia* swamp

Stand Metrics

2.9	Total no. of species:
228.3	Herb height (cm)
49.4	Open water (%)
13.9	Bare ground (%)
61.7	Litter cover (%)
0.0	Bryophyte cover (%)
98.9	Herb cover (%)
9	No. Samples

The nine samples are a reasonable match to the reference NVC type, although they have very frequent reed which is not a feature of the NVC S13 vegetation.

**S14 a *Sparganium erectum* swamp,
Sparganium erectum sub-community**

Stand Metrics

5	Mean species number
175	Herb height (cm)
36	Open water (%)
32	Bare ground (%)
46	Litter cover (%)
0	Bryophyte cover (%)
99	Herb cover (%)
5	No. samples

Five samples in the group, with a reasonable match to NVC.

**S14 b *Sparganium erectum* swamp,
Alisma plantago-aquatica sub-community**

A single sample of this NVC type.

**S14c *Sparganium erectum* swamp,
Mentha aquatica sub-community**

Stand Metrics

9.6	Mean species number
167.1	Mean height (cm)
61.2	Mean % of open water
16.3	Mean % of bare ground
65.2	Mean % of litter cover
3.2	Mean % bryophyte cover
93.7	Mean % herb cover
26	Total number of samples

Relationship with the NVC

The fit with the reference NVC type is reasonable, with *Sparganium* constant and a range of diagnostic preferentials of the sub-community present in the data set at high frequency. However, reed is frequent and often dominant in the sample group but largely absent in the NVC reference type, and *Lemna minor* unusually frequent and abundant in the Broads. This suggests the stand is transitional to the newly proposed *Lemna minor* sub-community of S4.

Distribution

All but two samples were from the Ant catchment.

S17 *Carex pseudocyperus* swamp

A single sample of this NVC type.

S19 *Eleocharis palustris* swamp

Three samples of this NVC type.

S20b *Schoenoplectus tabernaemontani* , *Agrostis stolonifera* sub-community

Stand Metrics

6.1	Mean species number
134.1	Mean height (cm)
15.9	Mean % of open water
35.0	Mean % of bare ground
40.5	Mean % of litter cover
1.8	Mean % bryophyte cover
86.8	Mean % herb cover
11	Total number of samples

Relationship with the NVC

This group of samples is not a good fit to the reference NVC type, containing constant *Phragmites* and also *Bolboschoenus maritimus*, both atypical of S20b. It may be transitional to the S21c vegetation described below. All stands were recorded in the Thurne.

Distribution

All samples were from the Thurne.

S21a *Bolboschoenus maritimus* swamp *Bolboschoenus maritimus* sub-community

Three samples of this very species-poor vegetation.

S21b *Bolboschoenus maritimus* swamp, *Atriplex prostrata* sub-community

Stand Metrics

7.6	Mean species number
69.5	Mean height (cm)
9.5	Mean % of open water
52.7	Mean % of bare ground
26.4	Mean % of litter cover
0.0	Mean % bryophyte cover
96.4	Mean % herb cover
11	Total number of samples

Relationship with the NVC

This small group of samples fits well within the NVC, although in the Broads stands *Aster tripolium* is much more frequent and the reed is more or less dominant rather than the *Bolboschoenus*. This is a distinctive Broadland feature of this community reflecting the reed rond position of the samples and the frequent historic management of the ronds for commercial reed.

Because of the frequent reed the stand has clear affinity to S4d.

Distribution

All of the samples were from the ronds of the river Yare.

S21c *Bolboschoenus maritimus* swamp, *Agrostis stolonifera* sub-community

Stand Metrics

8.3	Mean species number
99.3	Mean height (cm)
9.1	Mean % of open water
32.1	Mean % of bare ground
56.3	Mean % of litter cover
0.0	Mean % bryophyte cover
95.0	Mean % herb cover
40	Total number of samples

Relationship with the NVC

The fit with the published NVC is a reasonable one, with the exception of the constancy and abundance of *Phragmites* which is high in the Broads samples. In the published community, reed is very infrequent and of low cover. As with S21b, it is considered that this is a distinctive Broadland feature of this community.

Distribution

The vegetation was most common on the Waveney river ronds and to a lesser extent the Yare. A few samples were recorded in the Thurne.

S22a *Glyceria fluitans* swamp,
Glyceria fluitans sub-community.

One sample of what Rodwell (1995) refers to as a water margin community. In Broadland it is most commonly found along dyke margins and in the foot drains of grazing marshes.

S24a *Phragmites australis*-*Peucedanum palustre* reed fen,
Carex paniculata sub-community

Stand Metrics

17.6	Mean species number
178.9	Mean height (cm)
27.8	Mean % of open water
10.9	Mean % of bare ground
66.4	Mean % of litter cover
14.3	Mean % bryophyte cover
97.5	Mean % herb cover
148	Total number of samples

Relationship with the NVC

This group of samples is a reasonable fit to the NVC bearing in mind the published reference has 12 samples and the current data set 148. There were 5.7 S24 character species per sample out of a possible 10.

The flora of the samples from the current survey is very similar although most of the constants and the preferentials of the community are at lower frequency than the published type. In particular, *Carex paniculata*, which is generally constant and dominant in the published accounts, is here reduced in both frequency (23%) and abundance. There is evidence of a general decline of *Carex paniculata* in the Broads, more especially in the near disappearance of S3 *Carex paniculata* swamp (George 1992), a trend which may have affected representation of this species in S24a. Nevertheless, the overall floristics of the vegetation suggest it is best placed in this sub-community.

Distribution

Samples are mostly from the Ant and Bure with small numbers from the Yare and Thurne.

S24b *Phragmites australis*-*Peucedanum palustre* reed fen,
Glyceria maxima sub-community

Stand Metrics

19.7	Mean species number
139.3	Mean height (cm)
20.0	Mean % of open water

17.7	Mean % of bare ground
59.5	Mean % of litter cover
7.6	Mean % bryophyte cover
96.8	Mean % herb cover
30	Total number of samples

Relationship with the NVC

This is a reasonable fit with the reference NVC sub-community, overall having the range of constants and preferentials found in the published type. There were 5.4 S24 character species per sample.

However, the current samples generally have reduced frequency of key species and overall are marginally less species-rich than the mean richness of the reference type at 21 species/sample. In particular, some of the key sub-community species such as *Glyceria maxima* are infrequent and generally not dominant. The decline of *Glyceria* in the Broads is discussed elsewhere.

Distribution

The majority of the samples are from the Yare, with a few from the Ant and Bure. One is from the Thurne.

- S24** ***Phragmites australis*-*Peucedanum palustre* reed fen,**
Intermediate between
(b) *Glyceria maxima* sub-community
(c) *Symphytum officinale* sub-community

Stand Metrics

19.9	Mean species number
157.3	Mean height (cm)
11.9	Mean % of open water
11.1	Mean % of bare ground
67.9	Mean % of litter cover
16.3	Mean % bryophyte cover
98.2	Mean % herb cover
88	Total number of samples

Relationship with the NVC

The community is a good fit to S24, with 5.5 character species per sample.

However, the fit to the sub-community is rather less clear. The samples from this survey have the preferentials that are common to both S24b and S24c, but preferentials that are specific to each individual community are either sparse or entirely absent. Overall, the samples from this survey are less species-rich than the published sub-communities. It has therefore been attributed as intermediate.

This is not surprising; S24c is mostly characteristic of the remnant fens of the Fenland basin such as Wicken and Woodwalton Fens and was not recorded in the Broads by Wheeler (1980a).

Distribution

The community is mostly from the Bure and the Ant.

S24d *Phragmites australis*-*Peucedanum palustre* reed fen, Typical sub-community

Stand Metrics

19.7	Mean species number
155.4	Mean height (cm)
26.9	Mean % of open water
12.0	Mean % of bare ground
65.7	Mean % of litter cover
15.4	Mean % bryophyte cover
96.9	Mean % herb cover
298	Total number of samples

Relationship with the NVC

The fit with the reference NVC sub-community is reasonable, with 5.9 character species per sample. S24d is the default sub-community in the NVC which does not have a strong identity of its own. It is defined by the absence of preferentials for the other sub-communities, having only the constants common to the whole community. The samples from this survey fit well with this profile. Samples in the current data set are 14% less rich than those in the reference sub-community (19.7 compared to 23 in the NVC) and have a reduced number of constants. This is the second largest S24 sub-community recorded in the survey.

Distribution

The community is mostly found in the Bure and the Ant with a few samples from the other catchments.

S24e *Phragmites australis*-*Peucedanum palustre* reed fen, *Cicuta virosa* sub-community

Stand Metrics

24.4	Mean species number
127.5	Mean height (cm)
45.6	Mean % of open water
12.7	Mean % of bare ground
49.6	Mean % of litter cover
26.7	Mean % bryophyte cover
92.5	Mean % herb cover
159	Total number of samples

Relationship with the NVC

The community again fits well into S24, with 5.9 character species per sample and a good range of the community constants at high frequency. It is also a reasonably good fit with the reference sub-community, which is defined by the range and diversity of wet rich-fen species typical of lower nutrient conditions.

However, as with all of the S24 sub-communities, the data from the current survey appear to be a little less species-rich than the published NVC types and with few preferentials of the sub-community and at lower frequency. *Cicuta* itself is particularly infrequent in the samples from the current survey. Rodwell (1995) follows Wheeler's (1980a) scheme in identifying a Typical variant which is less species-rich, and a *Carex lasiocarpa* variant which is the richer type. Both are recorded in this survey, although the *Carex lasiocarpa* variant is less common. It occurs mostly in the Ant valley (for instance at Sutton Fen), and appears to be floristically quite close to Wheeler's (1980a) *Peucedano-Phragmitetum caricetosum* which Rodwell placed in M9. Rodwell does not present community tables for the two variants, so a formal split in the samples cannot be made.

Distribution

The community is particularly characteristic of the Ant, with large numbers of samples also from the Bure. There are some samples from the small tributary valleys. It appears to be absent from the Yare, Thurne and Waveney.

S24f *Phragmites australis*-*Peucedanum palustre* reed fen, *Schoenus nigricans* sub-community

Stand Metrics

20.1	Mean species number
136.4	Mean height (cm)
25.7	Mean % of open water
10.9	Mean % of bare ground
67.8	Mean % of litter cover
14.8	Mean % bryophyte cover
97.0	Mean % herb cover
175	Total number of samples

Relationship with the NVC

In this group of samples, *Cladium* is often dominant over reed although this is not always the case. Overall the vegetation fits within the broad scope of S24f, although as with all of the sub-communities of S24, the preferentials are rather less frequent than in the published examples (including *Schoenus*), although the samples are not significantly more species-poor than the reference type which recorded 21 species per sample. The group of 175 samples in the current survey is vastly greater than the 21 used to define the NVC sub-community, so a close fit is rather unlikely.

Distribution

The community was recorded in the Bure, Ant and Thurne, with a scattering of samples in the tributary valleys.

S24g *Phragmites australis*-*Peucedanum palustre* reed fen,
Myrica gale sub-community

Stand Metrics

15.5	Mean species number
176.4	Mean height (cm)
25.8	Mean % of open water
8.3	Mean % of bare ground
74.3	Mean % of litter cover
9.1	Mean % bryophyte cover
97.8	Mean % herb cover
331	Total number of samples

Relationship with the NVC

The Broads stands are clearly within S24 with a mean number of character species per sample of 5.9. This is by far the largest sample group of the S24 sub-communities.

The community has broad affinity to S24g, with frequent *Myrica gale*, although the other associates such as *Salix repens* are present at reduced frequency. Overall, however, the vegetation is consistent with the NVC type, being dominated by reed or *Cladium*, sometimes both, and including a number of stands of unharvested or long-rotation sedge fen where *Myrica* can be very dense. Overall the community is the poorest of the S24 sub-communities, with the current Broads samples being significantly poorer than those published in the NVC (with 15.5 and 20 species per sample respectively). Considering that the 331 samples of the current data set are being matched to just 12 in the NVC data set, a close match is again unlikely.

Distribution

This community is principally found in the Bure and the Ant, plus a hand full of samples in tributary valleys.

BS3 *Phragmites australis* - *Calamagrostis canescens* fen

Stand Metrics

11.7	Mean species number
146.5	Mean height (cm)
8.9	Mean % of open water
11.2	Mean % of bare ground
74.3	Mean % of litter cover
7.3	Mean % bryophyte cover
97.5	Mean % herb cover
154	Total number of samples

Relationship with the NVC

Most of the samples gathered here are taken from TWINSPAN end group 177, although the final grouping has been assembled by inspection.

The key feature of the vegetation is the constancy and co-dominance of *Calamagrostis canescens* and *Phragmites*. *Juncus effusus* is also very frequent and can be dominant in some stands. Other distinctive tall herbs at around 50% frequency are *Eupatorium cannabinum* and *Cirsium palustre*. Particularly characteristic is the range of species at frequency 10-40% that is characteristic of dryer fens or contact communities (*Eurynchium praelongum*, *Brachythecium rutabulum*, *Dryopteris carthusiana*, *Arrhenatherum elatius*), mild disturbance (*Rubus fruticosus*, *Cirsium arvense*) or eutrophic conditions (*Urtica dioica*, *Galium aparine*).

Species of wetter, low nutrient rich-fens generally regarded as of higher quality in conservation terms are present, but rather infrequent. There is occasional *Peucedanum palustre* and *Lythrum salicaria*, plus a little *Juncus subnodulosus* and *Thelypteris palustris*. Then, there is a very long list of species recorded at 10% frequency or less. This tail is very eclectic in the habitat conditions it suggests, including poor-fen and rich-fen species, and those indicative of much of the whole spectrum of habitat types. It suggests the very wide amplitude of this community in terms of its origins and habitat locations. The long list of infrequent species includes some uncommon fen plants such as *Pyrola rotundifolia* and *Dryopteris cristata*.

The community does not match with any of the NVC reference communities, where there is no clear placement of *Calamagrostis*-dominated vegetation. It does not accord with Rodwell's associate Group B, and therefore does not fall within S24 which is the most obvious placement. Neither do the associates described here reflect any of his other associate groups, which suggests it falls outside of the NVC altogether. It is at the margins of the eutrophic fens, whereby indicators of high nutrient conditions such as *Urtica dioica* and *Galium aparine* are present but much less frequent than in S26, OV26 and related communities. None of these adequately accommodate *Calamagrostis canescens* vegetation. Consequently, as the sample group is large, and the vegetation distinctive, an entirely new fen community is proposed.

Two particularly common locations for this community are along dyke margins which are more elevated and disturbed than the adjacent wet fen compartments, and dryer areas that have been reclaimed from scrub.

Distribution

Most of the samples were from the Thurne, with good numbers of samples from the Bure and the Ant, plus a few from tributary valleys.

BS4 *Calamagrostis canescens* fen

Stand Metrics

6.1	Total no. of species:
91.9	Herb height (cm)
17.5	Open water (%)
26.3	Bare ground (%)
54.4	Litter cover (%)
0.1	Bryophyte cover (%)
96.9	Herb cover (%)
8	No. samples

Relationship with the NVC

There are only eight samples from this community, most of which are very species-poor. It is a rather ill-defined vegetation type, very strongly dominated by *Calamagrostis canescens* but with patchily abundant *Juncus effusus*, *Phragmites* and *Agrostis stolonifera*. There is no analogous NVC type, hence this is proposed as a new community. It is distinct from the BS3 *Phragmites-Calamagrostis* vegetation in its overwhelming dominance of *Calamagrostis* and its severely reduced complement of rich-fen species. It has nearly half the species-richness. Most of the rest of the flora is indicative of dry fens, contact communities and eutrophic situations. Scrub species are also a marked feature of the flora. It is possible that the community is associated with scrub clearance on dryer fen sites.

The occurrence of *Pyrola rotundifolia* in one sample from the Ant catchment is notable.

Distribution

Most samples are from the Ant, with two from the Thurne and one from the Yare.

Intermediate:

S24 *Phragmites australis*-*Peucedanum palustre* reed fen,

S25 *Phragmites australis*-*Eupatorium cannabinum* fen

Stand Metrics

14.1	Mean species number
151.8	Mean height (cm)
23.3	Mean % of open water
12.5	Mean % of bare ground
67.4	Mean % of litter cover
8.3	Mean % bryophyte cover
96.4	Mean % herb cover
1025	Total number of samples

Relationship with the NVC

This community has been placed as intermediate between S24 and S25. A very large data set of more than 1000 samples, the community is too indistinct to place

in either community. It has some of the preferentials of S24 – notably *Peucedanum palustre* – with around 3-4 S24 “character species” per sample. It also has a range of associate group B species which Rodwell uses to characterise S25, but these are often low in frequency. As the overall floristics appears to be a blend of associate groups A and B, the vegetation has been placed as an intermediate community between S24 and S25.

It is between S24 and S25 in species-richness.

Distribution

The community is widely distributed throughout the five rivers. Most samples are found in the Ant, Bure and Thurne, with fewer in the Yare and only a handful in the Waveney and tributary valleys. For some, such as the Yare, it is the closest that much of the fen ever gets to true S24.

***Eleocharis uniglumis* swamp**

This rare vegetation of three samples is found in a few swampy hollows dominated by this uncommon plant and has no NVC equivalent. Its few samples and fragmentary nature do not justify proposal of a new community.

***Myrica gale* fen**

This community is dominated by tall dense bushes of *Myrica*. There are only a few samples in the stand. It is also a poor fit to the NVC but has some affinity to an impoverished form of S24g. Again, its few samples and fragmentary nature do not justify proposal of a new community.

S25a *Phragmites australis*-*Eupatorium cannabinum* fen, *Phragmites australis* sub-community

Stand Metrics

11.1	Mean species number
137.9	Mean height (cm)
6.1	Mean % of open water
16.0	Mean % of bare ground
60.1	Mean % of litter cover
19.0	Mean % bryophyte cover
95.5	Mean % herb cover
41	Total number of samples

Relationship with the NVC

This is a reasonable fit to S25, with all of the community constants and a good range of sub-community preferentials. However, *Carex riparia*, *Agrostis stolonifera*, *Solanum dulcamara* and *Calystegia sepium* are all much more frequent than the published type. The vegetation is also rather patchy. It includes stands where some species such as *Carex riparia* can be very dominant and such samples show clear transition to BS1 *Phragmites australis*-*Carex riparia* vegetation described elsewhere.

Distribution

Nearly all of the samples are from the Thurne, with a handful scattered around all the other catchments except the Waveney.

S25c *Phragmites australis-Eupatorium cannabinum* fen, *Cladium mariscus* sub-community

Stand Metrics

9.5	Mean species number
154.8	Mean height (cm)
22.5	Mean % of open water
9.8	Mean % of bare ground
74.5	Mean % of litter cover
2.3	Mean % bryophyte cover
94.7	Mean % herb cover
129	Total number of samples

Relationship with the NVC

This is a very good fit with the reference NVC vegetation type. *Eupatorium cannabinum* itself is at rather low frequency, but otherwise the vegetation has close affinity with the published sub-community. *Phragmites* generally dominates over *Cladium*.

Distribution

This is a community principally of the Thurne, with some samples from the Ant and a few from the Bure.

S27a *Potentilla palustris-Carex rostrata* tall herb fen *Carex rostrata-Equisetum fluviatile* sub-community

Stand Metrics

15.0	Total no. of species:
58.6	Herb height (cm)
55.0	Open water (%)
20.0	Bare ground (%)
57.9	Litter cover (%)
1.1	Bryophyte cover (%)
97.1	Herb cover (%)
7	No. samples

Seven samples make up this species-rich and rather distinctive wet fen community. The fit to the NVC is good. Most of the samples are from the Bure with a couple from the Yare.

S27b *Potentilla palustris*-*Carex rostrata* tall herb fen,
Lysimachia vulgaris sub-community.

Stand Metrics

14.4	Mean species number
140.6	Mean height (cm)
54.3	Mean % of open water
20.2	Mean % of bare ground
49.8	Mean % of litter cover
16.1	Mean % bryophyte cover
94.4	Mean % herb cover
72	Total number of samples

Relationship with the NVC

This is a rather heterogeneous community with very variable patterns of dominance, whereby stands can appear visually to be quite different from each other. The fit with the reference NVC type is reasonable to poor, although most of the community constants are less frequent in the current data set than in the type community. This includes *Carex rostrata* itself, which when present can entirely dominate the vegetation, and *Potentilla palustre*, which are both present at around 30% frequency. *Menyanthes trifoliata* occurs at around 20% frequency and like *C. rostrata* can dominate in suitable situations such as swampy hollows or grown-over foot drains. Many of the preferentials of the reference sub-community are also reduced in frequency, and in many ways this is an unsatisfactory grouping of samples and matching to reference NVC types. While there is a broad accommodation of the data under S27b, the nature of this vegetation type in Broadland would benefit from further consideration.

Distribution

This is principally a community of the Bure and Ant catchment, with a few samples from the Yare and Waveney.

BS5 *Dryopteris cristata*-*Sphagnum* species fen

Stand Metrics

16.4	Mean species number
130.2	Mean height (cm)
4.1	Mean % of open water
6.7	Mean % of bare ground
21.0	Mean % of litter cover
72.2	Mean % bryophyte cover
87.3	Mean % herb cover
57	Total number of samples

Relationship with the NVC

This most distinctive of the Broadland communities has long been recognised, but has usually been described in the context of woodland and scrub and is not

recognised specifically by the NVC as a fen type. Rodwell (1991a) has placed broadly similar vegetation within the W2b *Salix cinerea*-*Betula pubescens*-*Phragmites australis* woodland, the *Sphagnum* sub-community. The ground layer of this wet woodland community has affinity with the fen character of the current sample set, but the associates in the reference vegetation are fewer and much less frequent than occur in the open fen samples described here. In addition, placing the current samples in a woodland community type is not reasonable. Wheeler (1980c) also placed similar vegetation within a woodland community, including stands with birch up to 4m tall, although later he refers to the community as a "...rather impoverished *Peucedano-Phragmitetum* type.." (Wheeler 1978) and it is not clear why he did not follow this observation and place it within S24. Parmenter's (1995) B24 *Sphagnum* spp-*Dryopteris* spp-*Thelypteris thelypteroides* open birch scrub community is also a similar vegetation type to Wheeler's and Rodwell's. The current survey would have excluded such dense canopies from sampling, so that the resulting floristic profile will be less affected by shading than those of Wheeler, Rodwell and possibly Parmenter.

In the herb layer, *Calamagrostis canescens* is constant, as is the uncommon and most characteristic plant, *Dryopteris cristata*. Both can be very dense beneath the reed in some stands. Also frequent are *Peucedanum palustre*, *Cirsium palustre*, *Thelypteris palustris*, *Eupatorium cannabinum*, *Juncus subnodulosus*, and *Typha angustifolia*. There is a range of infrequent species of Broadland rich fens, such as Group A associates plus *Myrica gale*, *Epilobium palustre*, *Osmunda regalis*, *Angelica sylvestris*, a range of sedges including, rarely, all three tussock sedges, and even some *Cladium mariscus*. Poor fen herbs are generally quite rare.

It is the poor-fen ground layer however, which is so distinctive in this community. In particular, a luxuriant ground cover of *Sphagnum* mosses, dominated *Sphagnum fimbriatum* but including *S. subnitens* and *S. squarrosum* which are frequent and can be abundant, and a host of less common species such as *S. inundatum*, *S. palustre*, *S. fallax*, *S. flexuosum*, *S. capillifolium* and *S. recurvum*. Frequent associates in the bryophyte layer are the poor-fen species *Aulacomnium palustre*, *Polytrichum commune* and *Calypogeia* species. Rich-fen bryophytes are few and generally very infrequent. The community is also the locus for a few diminutive poor-fen herbs which are uncommon on the floodplains of Broadland, utilising the raised *Sphagnum* hummocks as their substrate. These include *Drosera rotundifolia* and *Pyrola rotundifolia*.

The mixed mire nature of the community, with the dominance of the ground layer *Sphagnum*, suggests this does not fit comfortably within S24. Even though it contains all but one of the associates which Rodwell uses to characterise S24, they are all at much lower frequency and abundance than is typical of the reference community. Because of this, and on the advice of Bryan Wheeler, it was therefore not placed within S24. Although it has affinity with M5 *Carex rostrata*-*Sphagnum squarrosum* mire, the floristics are no closer to this than S24. Hence, until a more detailed phytosociological treatment is available, it has been given new community status.

Distribution

This is a community of the Ant and Thurne, with a handful of samples from the Bure. The two samples from the Waveney did not contain *D. cristata*.

Intermediate:

S27b *Potentilla palustris*-*Carex rostrata* tall herb fen,
Lysimachia vulgaris sub-community.

M5 *Carex rostrata*-*Sphagnum squarrosum* mire.

This set of samples, all from Mrs Myhill's Marsh from the Thurne catchment is difficult to place in the NVC. The principle species of Rodwell's associate group D used to define S27 are all represented (including all three of the *Calliergon*/*Calliergonella* species he refers to) except *Agrostis stolonifera*. It has a broad range of the constants and preferentials of the *Lysimachia vulgaris* sub-community, providing the base-rich tall herb fen element to the flora, albeit at reduced frequency. It also has a strong representation of acid mire species including *Carex curta* and a range of *Sphagna*, and constant but not abundant *Juncus effusus*. This places it close to M5, although in Rodwell (1991b) this is an uncommon community with a strongly western and northern distribution. Intermediate status between these two NVC communities is perhaps the most satisfactory placement, but sampling elsewhere and further analysis may suggest these samples would be part of a new mixed-mire community worthy of recognition.

It is a rich vegetation type, with a mean number of species per sample of 18.5. It appears to be unique in Broadland. The other analogous vegetation type described by Wheeler (1978) from East Ruston in the Ant catchment has been lost due to habitat destruction. The other mixed mire vegetation (S24 *Phragmites-Peucedanum* tall herb fen, BS5 *Dryopteris cristata*-*Sphagnum* spp sub-community) is a floodplain fen of quite different hydrology and species composition to the valley mire community described here.

A.3 Eutrophic Tall Herb Fens

In this section are gathered all of the sample sets of eutrophic fen. The Yare is the locus *par excellence* for this vegetation type. The fit of many of the vegetation types recorded during this survey to NVC reference communities is rather poor, and a number of new units are proposed. For instance, three new sub-communities, and one new variant of an established sub-community, are suggested for S26. The evidence suggests that there is a strong case for thorough revision of this NVC community, together with communities dominated by *Carex riparia* and *C. acutiformis* which also feature strongly here. The NVC has apportioned some eutrophic fen to OV26 in the Open Vegetation chapter, for reasons that are not entirely clear. An improved appreciation of this vegetation would be helped if these NVC types were considered together.

S26a *Phragmites australis*-*Urtica dioica* fen,
Filipendula ulmaria sub-community.

Stand Metrics

8.1	Mean species number
176.1	Mean height (cm)
5.2	Mean % of open water
7.5	Mean % of bare ground
83.2	Mean % of litter cover
1.0	Mean % bryophyte cover
99.3	Mean % herb cover

Relationship with the NYC

Overall fit with the reference S26a is good. The Broads vegetation has unusual frequency of *Calystegia sepium* and the pond sedges, *Carex acutiformis* and *C. riparia*. *Filipendula* is less frequent than in the published type, but otherwise the fit is good with this the most species-poor of the sub-communities.

Distribution

The bulk of the community was recorded in the Yare, but there were examples from all the main river catchments.

S26b *Phragmites australis-Urtica dioica* fen,
Arrhenatherum elatius sub-community.

Stand Metrics

8.2	Mean species number
148.8	Mean height (cm)
1.7	Mean % of open water
7.6	Mean % of bare ground
78.3	Mean % of litter cover
0.4	Mean % bryophyte cover
99.3	Mean % herb cover
96	Total number of samples

Relationship with the NVC

The community is a good fit with the reference NVC type. *Heracleum sphondylium* is reduced in frequency, while *Carex riparia* is a little more frequent but otherwise the Broads samples are quite typical of the published S26b.

Distribution

The Yare and Thurne are the main valleys for S26b, with some in the Waveney and just a couple each in the Ant and Bure.

S26b *Phragmites australis-Urtica dioica* fen,
Arrhenatherum elatius sub-community
Saline Variant

Stand Metrics

8.1	Mean species number
121.4	Mean height (cm)
4.8	Mean % of open water
4.8	Mean % of bare ground
89.5	Mean % of litter cover
0.0	Mean % bryophyte cover
99.5	Mean % herb cover
21	Total number of samples

Relationship with the NVC Scheme

The community is a good fit with the main S26b NVC unit, with perhaps *Arrhenatherum* more frequent and abundant than the published examples, and *Urtica* less.

The key difference (and the reason the community has been placed in a newly proposed variant) is the number and on occasion frequency of high saltmarsh plants, particularly *Atriplex prostrata* and *Elytrigia atherica*. However, this influence was not deemed sufficiently strong to erect a new saline sub-community of S26.

Distribution

With one exception from the Thurne, all samples were recorded in the Waveney and Yare.

S26d *Phragmites australis-Urtica dioica* fen, *Epilobium hirsutum* sub-community.

Stand Metrics

8.6	Mean species number
179.4	Mean height (cm)
11.0	Mean % of open water
6.8	Mean % of bare ground
82.7	Mean % of litter cover
0.4	Mean % bryophyte cover
98.8	Mean % herb cover
281	Total number of samples

Relationship with the NVC

The fit between the reference NVC type and this large group of samples is reasonable. *Epilobium hirsutum* is less frequent than the published type, and *Calystegia sepium* much more so, but otherwise this is the best place for this group of samples.

S26 *Phragmites australis-Urtica dioica* fen

New Sub-community: BS(e) *Calamagrostis canescens* sub-community

Stand Metrics

9.5	Mean species number
155.6	Mean height (cm)
16.0	Mean % of open water
7.2	Mean % of bare ground
85.4	Mean % of litter cover
1.4	Mean % bryophyte cover
99.1	Mean % herb cover
134	Total number of samples

Relationship with the NVC

The constant and abundant reed and *Urtica*, along with all of Rodwell's group C associates, places this community in S26. However, the large set of samples from this survey has some distinctive features. These include constant and often abundant *Calamagrostis canescens*, together with a suite of rich-fen tall herbs (including many of associate groups A and B which are the basis of S24 and S25) at generally low frequency. *Carex acutiformis*, *Phalaris arundinacea* and *C. riparia* are all occasional to frequent in the community and can be abundant. There is then a long tail of species less than 10% frequency reflecting a very wide range of habitat types

from dry through to wet fens. Mostly they reflect more eutrophic conditions, but there are rare records for *Potentilla palustris*, *Menyanthes trifoliata*, *Dryopteris cristata*, and *Carex elata* from the less fertile end of the spectrum. This new sub-community bridges between S26 and S24.

It is distinct from the newly proposed *Phragmites-Calamagrostis* community described above in its lack of *Juncus effusus*, the greater frequency and abundance of eutrophic S26 plants and wider range of Broadland tall herb fen species. Hence it has been retained in S26 but nominated as a new sub-community.

Distribution

The community is most characteristic of the Bure and Thurne, with a number of samples from the Yare and Ant.

S26 *Phragmites australis-Urtica dioica* fen

New sub-community:
BS(f) *Carex* species fen

Stand Metrics

15.9	Mean species number
163.2	Mean height (cm)
6.8	Mean % of open water
11.1	Mean % of bare ground
75.0	Mean % of litter cover
6.2	Mean % bryophyte cover
100.0	Mean % herb cover
15	Total number of samples

Relationship with the NVC

Again, the vegetation includes all of Rodwell's associate group C placing it comfortably within S26, but there is no real affinity with the reference sub-communities.

It is a relatively rich community dominated by mixtures of *Urtica dioica*, *Phragmites* and the three bulky fen sedges *Carex paniculata*, *C. riparia* and *C. acutiformis*. The dryland bryophytes *Brachythecium rutabulum* and *Eurynchium praelongum* are unusually frequent, perhaps utilising sedge stools as a dry substrate. There is a modest range of the associates typical of S24 and S25 at frequencies of 20-50%, otherwise the main bulk of the flora is taken from S26 and related eutrophic vegetation types. The tail of infrequent species once again reflects a wide range of substrates and hydrologies, some of which are more normally associated with high quality fen types, for instance one record for *Carex appropinquata*.

The samples have been ascribed to a newly proposed sub-community of S26, named for the three characteristic sedge species. This sub-community forms a bridge to S24b and S24c, the two more eutrophic sub-communities of S24.

Distribution

These samples were mostly from the Waveney with some from the Bure and a single sample from the Thurne.

- S26** ***Phragmites australis-Urtica dioica* fen,**
New Sub-community:
BS(g) Species-poor sub-community

Stand Metrics

4.5	Mean species number
196.5	Mean height (cm)
14.7	Mean % of open water
6.2	Mean % of bare ground
75.3	Mean % of litter cover
0.3	Mean % bryophyte cover
99.9	Mean % herb cover
120	Total number of samples

Relationship with the NVC

This community is essentially reed over *Urtica* with a range of associates typical of fertile and to a degree disturbed fens. Its great species-poverty makes it difficult to place in the NVC. All of Rodwell's associate group C are present, placing it in S26, but most are at frequencies below 10%. Many of the key associates of OV26, the other obvious choice, are rare or absent in the current vegetation. It has little relationship with S4, other than a high cover of reed. Overall it has most affinity to S26 *Phragmites-Urtica* fen but is impoverished even compared to this and has no affinity to any of the reference sub-communities. Because of the large sample set and its distinctive species-poverty, this has been assigned a new sub-community.

Distribution

Characteristic of the Yare and the Waveney, the community is also found in the Bure and in fragments in the other catchments.

Intermediate:

- S26** ***Phragmites australis-Urtica dioica* fen,**
***Filipendula ulmaria* sub-community.**
S5a ***Glyceria maxima* swamp,**
***Glyceria maxima* sub-community**

Stand Metrics

4.3	Mean species number
150.0	Mean height (cm)
26.5	Mean % of open water
0.5	Mean % of bare ground
90.5	Mean % of litter cover
0.0	Mean % bryophyte cover

100.0	Mean % herb cover
20	Total number of samples

Relationship with the NVC

This community is dominated by *Glyceria* with constant reed and both sub-species of *Urtica dioica*. It has few species of conservation concern, and very few associates at any frequency. It has been placed as intermediate between the two species-poor sub-communities of the parent NVC reference types. There are insufficient samples and too indistinct a flora to warrant a new sub-community.

Distribution

The community is restricted to the Yare, bar one sample from the Waveney.

OV26b *Epilobium hirsutum* community, *Phragmites australis-Iris pseudacorus* sub-community

Stand Metrics

11.2	Mean species number
146.7	Mean height (cm)
7.5	Mean % of open water
8.0	Mean % of bare ground
83.3	Mean % of litter cover
0.5	Mean % bryophyte cover
97.9	Mean % herb cover
139	Total number of samples

Relationship with the NVC

The sample set is a good fit with the nominated reference NVC community, although there are some significant differences. *Epilobium hirsutum* is generally infrequent, as are most of the preferentials of the reference sub-community.

The structure is relatively homogeneous at chest height or above, dominated by tall plants with very little in terms of understory or ground layer. One or other of the tall helophytes – *Phragmites*, *Glyceria maxima* or *Phalaris arundinacea* - is usually dominant, rarely do all three co-dominate and only one may be present in any particular sample. There is nearly always one of the pond sedges – *Carex acutiformis* or *C. riparia* – and very often both. The sedges can be dense, and their prominence is unusual in OV26b, suggesting some transition to the newly proposed BS(f) *Carex* spp sub-community of S26. Field experience suggests *Carex riparia* is favoured in swamplier situations closer to the river or broads. The broad-leaved herb most characteristic of the community (and overall the most frequent species) is *Urtica dioica dioica*, sometimes with the uncommon *Urtica dioica galeopsifolia*. Other frequent tall herbs are *Eupatorium cannabinum*, *Iris pseudacorus* and *Filipendula ulmaria*, supplemented by the climbers *Calystegia sepium*, *Galium palustre* and to a lesser extent *Solanum dulcamara*. *Epilobium hirsutum* is very locally prominent but is absent from most samples. Then there is a relatively long list of infrequent associates of wetter fens and also of disturbed situations.

It is typical of all the eutrophic tall herb fens in that it can be very patchy and the patterns of dominance can shift over relatively short distances. It is a very dense vegetation, generally unmanaged or with light management only, and is often difficult to penetrate because of clinging sedge leaves and binding scramblers.

Distribution

The majority of samples are from the Yare, with small numbers from the Bure and Waveney.

OV26c *Epilobium hirsutum* community, *Filipendula ulmaria*-*Angelica sylvestris* sub-community

Stand Metrics

16.1	Mean species number
113.8	Mean height (cm)
3.0	Mean % of open water
13.8	Mean % of bare ground
74.4	Mean % of litter cover
0.1	Mean % bryophyte cover
91.3	Mean % herb cover
8.0	Total number of samples

Relationship with the NVC

The eight samples from this community are a reasonable fit to the NVC.

Distribution

The community is mostly from the Yare, with two samples from the Thurne and one from the Bure.

OV26d *Epilobium hirsutum* community, *Arrhenatherum elatius*-*Heracleum sphondylium* sub-community

Two samples were recorded. They are best placed in OV26d but with a poor fit.

S28a *Phalaris arundinacea* fen, *Phalaris arundinacea* sub-community

Three samples from this species-poor community type.

S28b *Phalaris arundinacea* Fen, *Epilobium hirsutum*-*Urtica dioica* sub-community

Stand Metrics

5.4	Mean species number
150.0	Mean height (cm)
10.5	Mean % of open water

6.9	Mean % of bare ground
89.8	Mean % of litter cover
0.0	Mean % bryophyte cover
100.0	Mean % herb cover
22	Total number of samples

Relationship with the NVC

This community is best matched with S28b, although the abundance and frequency of reed and *Urtica* species suggests some affinity with S26 *Phragmites australis-Urtica dioica* fen. Otherwise there are few other distinctive features of this vegetation.

Distribution

The community is largely found in the Yare although there are some stands in the Ant and one sample in the Bure.

A.4 Saltmarsh Communities

SM13d *Puccinellia maritima* saltmarsh, *Plantago maritima*-*Armeria maritima* sub-community

Only two samples from this community, recorded from the Yare.

SM16a *Festuca rubra* saltmarsh, *Puccinellia maritima* sub-community

Stand Metrics

8.2	Mean species number
15.3	Mean height (cm)
0.2	Mean % of open water
16.5	Mean % of bare ground
11.3	Mean % of litter cover
0.0	Mean % bryophyte cover
55.8	Mean % herb cover
26	Total number of samples

Relationship with the NVC

The fit with the reference NVC community is reasonable, with the exception that *Festuca rubra* has been replaced with an open tier of very short *Phragmites australis*. The reed is clearly very stunted in this saline habitat and may be at the margins of its range of tolerance.

Distribution

Most examples were from the river faces of the Yare reed ronds. However, four were from the Ant, a surprise as this is thought to be a freshwater catchment.

**SM16b *Festuca rubra* saltmarsh,
Juncus gerardii sub-community**

Stand Metrics

7.5	Mean species number
40.3	Mean height (cm)
3.8	Mean % of open water
43.4	Mean % of bare ground
36.6	Mean % of litter cover
0.0	Mean % bryophyte cover
100.0	Mean % herb cover
29	Total number of samples

Relationship with the NVC

The fit with the NVC reference type is reasonable. This community has close affinity with the previous, except here *Juncus gerardii* has replaced *Puccinellia maritima* as the dominant. The replacement of *Festuca rubra* with *Phragmites australis* is much more marked here, with the reed being more frequent, more abundant and taller. From a distance, the vegetation may take on the appearance of a rather open and stunted reedbed. Only close up may it be apparent that this remains a saltmarsh vegetation type, with an unusual reed component. There is no other significant fen component.

Distribution

The community is found mostly on the river ronds of the lower Yare, with some samples from the lower Waveney.

**SM16ci *Festuca rubra* saltmarsh,
Festuca rubra-*Glaux maritima* sub-community,
Agrostis stolonifera variant**

Stand Metrics

8.6	Mean species number
86.2	Mean height (cm)
16.2	Mean % of open water
32.4	Mean % of bare ground
47.9	Mean % of litter cover
0.0	Mean % bryophyte cover
98.5	Mean % herb cover
17	Total number of samples

Relationship with the NVC

There is a good correlation with the NVC reference community, even down to variant level where the abundance and frequency of *Agrostis stolonifera* places this in the eponymous vegetation type. As with the previous vegetation types, the replacement of *Festuca rubra* with reed is distinctive, to the degree that in this

community reed is now sometimes dominant and the mean height of the vegetation is significantly taller. Although the community is still clearly saltmarsh, the increase in reed, *Agrostis*, *Atriplex prostrata* and for the first time, some fen species, suggests transitional conditions with the brackish S4d community.

Distribution

The community is typical of the lower ronds of the Waveney and Yare, with one sample from the Thurne.

SM20 *Eleocharis uniglumis* saltmarsh

Two samples from the Thurne were recorded.

SM23 *Spergularia marina*-*Puccinellia distans* saltmarsh

Only three samples were recorded, a reasonable fit with the NVC, from the Yare.

SM24 *Elytrigia atherica* saltmarsh

Four samples of this reed over saltmarsh community were recorded from the Yare.

A.5 Contact Communities

The communities gathered in this section were not originally target fen types for the survey. However, they all carry a range of fen species, particularly reed, which in the field gave the impression of fen character and hence they were sampled. Ultimately, the analysis and classification has separated these into a range of dry rush pastures and other fen-marginal communities which are presented in this section. They are not discussed in Section 4.

MG13 *Agrostis stolonifera*-*Alopecurus geniculatus* grassland

Stand Metrics

10.4	Mean species number
37.1	Mean height (cm)
4.8	Mean % of open water
53.3	Mean % of bare ground
20.8	Mean % of litter cover
1.3	Mean % bryophyte cover
90.0	Mean % herb cover
24	Total number of samples

Relationship with the NVC

This is a good fit with the two constants typical of the reference NVC community are also constant and dominant here.

The community appears to have a flora typical of a slightly drier range of habitats than the published type with more frequent dryland and meadow grasses, and more species indicating improved grassland, such as *Lolium perenne*. There is a

greater representation of species indicative of higher nutrients and more disturbance than the published type. Reed is markedly more frequent in the Broadland samples, reflecting the contact with adjacent fen stands.

Distribution

It is predominantly found in the floodplain areas of the Yare and Waveney with some samples from the Ant and a couple from the Yare.

MG10a *Holcus lanatus*-*Juncus effusus* rush pasture, Typical sub-community

Stand Metrics

9.3	Mean species number
79.8	Mean height (cm)
14.4	Mean % of open water
8.1	Mean % of bare ground
74.5	Mean % of litter cover
0.5	Mean % bryophyte cover
95.5	Mean % herb cover
64	Total number of samples

Relationship with the NVC

All of the community constants of the NVC reference type are also constant in the Broads samples. The Typical community is characterised by a lack of the preferentials of the other sub-communities at the given frequency. This is certainly the case with the Broadland data and the group is therefore a good fit to the NVC.

Probably the most significant difference is the high frequency of reed which can in places be abundant or even dominant. Reed does not feature in any of the sub-communities of the reference MG10 vegetation types, perhaps because their samples were taken from continually grazed pastures. The Broads samples are mostly from within a fen context, either being from the margins of old fens where grazing has been introduced or more often where grazing has been relaxed or abandoned.

There is a long tail of infrequent samples reflecting the large size of the data set and variety of contexts the vegetation has been recorded from.

Distribution

The community is especially common in the Thurne catchment with many samples also from the Ant. There are a few from Yare and one from the Waveney.

**MG10b *Holcus lanatus*-*Juncus effusus* rush pasture,
Juncus inflexus sub-community**

Stand Metrics

13.0	Mean species number
72.8	Mean height (cm)
0.0	Mean % of open water
33.6	Mean % of bare ground
40.0	Mean % of litter cover
1.7	Mean % bryophyte cover
93.0	Mean % herb cover
51	Total number of samples

Relationship with the NVC

This group of samples is a good fit to the NVC with a good spread of community constants and sub-community preferentials.

The community shares the unusual frequency and abundance of *Phragmites* observed with the MG10a samples described above, presumably for similar reasons.

Distribution

The community is almost exclusively from the Waveney, with only a small number of samples from the Yare.

OV27 *Chamerion angustifolium* community

Three samples form this minor group, assigned to OV27 because of the frequency and abundance of *Chamerion*. However, the samples unusually have much *Phragmites* and *Phalaris*, reflecting the fen context.

OV30 *Bidens tripartita*-*Polygonum amphibium* community

Only one sample was recorded from this community.