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The Water Regime Requirements and the Response to Hydrological Change of Grassland Plant Communities

DEFRA-commissioned project BD1310
Final report to the Department for Environment, Food and Rural Affairs

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Executive Summary

Floodplain hay meadows are a high conservation priority. They hold species rich vegetation, support a wealth of wildlife and are a quintessential part of the English landscape. The remaining area of such meadows is very small and at risk from inappropriate management. DEFRA is helping to protect this habitat type and to encourage its restoration via the Environmentally Sensitive Area (ESA) and Countryside Stewardship schemes.

Previous research has shown that the plant communities of floodplain meadows are very sensitive to soil water regime and therefore careful hydrological management is essential for their conservation. This report describes the water-regime requirements of floodplain grassland communities in quantitative terms, using techniques developed in previous DEFRA(MAFF)-funded research (BD0209).

The approach consisted of gathering botanical data from 18 sites throughout England that support species-rich wet grassland. At each site, between 60 and 800 (depending on the size of site) positions were sampled in terms of their botanical composition. The water regime of each position was individually modelled and the models' outputs were validated against dipwell observations of water-table behaviour taken in the field.

The total botanical data set consisted of 3904 samples. Data analysis divided these into 14 community types, which gave good coverage of the range of floodplain grassland vegetation found in England and Wales. The mean water regime of each of these types was shown to be distinct, suggesting water-regime is an important, perhaps the most important, determinant of plant community composition. The range of regimes preferred by each community type is presented graphically in the appendices to the report, using the concept of Sum Exceedence Values, which provide a method for quantifying water regime that is transferable between sites. The preferred water regimes of individual species are also appended to the report, updating those presented in an earlier report (BD0209), using the now larger data set.

The ranges of phosphorus availabilities for a subset of community types are presented. Differences between communities suggest that phosphorus availability is an important factor in determining community composition, but appears to be secondary to water regime. Other measures of soil chemistry (pH, extractable potassium, total nitrogen) were found not to differ significantly between communities over the range sampled. All sites were unfertilised, neutral mesotrophic grasslands.

At a species level, one readily available piece of information about water-regime preference is the moisture score (or F-value) proposed by Ellenberg for European vegetation and recently corrected for the British situation by Hill *et al*. It is possible to derive an equivalent score for a community by taking a mean of the values published for its constituent species. Correlating the degree of waterlogging, as described by Sum Exceedence Values, with the mean Ellenberg F-value for each sampled quadrat, gave a clear linear relationship. This suggests that the published F-values could potentially be used to estimate the water-regime preferences of vegetation types that were not explicitly studied within this project.

Three sites were studied in order to determine the rate of community change in response to a managed alteration in their hydrology. Results revealed that increasing the degree of waterlogging led to a rapid alteration in community type and to a loss of species richness. Vegetation experiencing a sudden increase in waterlogging showed a change in its community type within a year of the new management being imposed. Due to a succession of extremely wet springs, the site designed to have a reduced amount of waterlogging also became wetter during the lifetime of the project and therefore no data are yet available with respect to community change in response to a site becoming drier. At another site where an increase in waterlogging had been relieved by subsequent management there was a tentative indication that the vegetation was beginning to recover, but this was also confounded by the recent run of wet springs.

The implications for DEFRA policy are discussed. It is recommended that scheme prescriptions, in addition to specifying minimum levels for water levels in water courses, should also set a limit as to how wet a site should

become, especially when species-rich grassland is one of the conservation objectives. Following from this, site managers should be given incentives to maintain or even enhance surface drainage systems in these situations. The very large database of species' and communities' water-regime requirements that is now available as a result of this work will allow future formulation of water-level prescriptions to be assessed for their effect on vegetation, prior to their implementation.

Not all the project's objectives were met due to a combination of access restrictions, resulting from Foot and Mouth Disease, extremely high rainfall over the period 1999-2001 and delays in scheme implementation by external agencies. The result was that it was not possible to monitor any site in which waterlogging decreased. Further data collection on some of the study sites, which have now undergone hydrological manipulation, would add value to the current dataset and allow the final objectives to be completed.

Scientific report (maximum 20 sides A4)

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1 INTRODUCTION

Traditionally managed hay meadows on floodplains tend to support diverse plant communities of great wildlife interest. Such grasslands were decimated during the last century, but are now the focus of much conservation effort and often the target for habitat creation projects. The Department for Environment, Food and Rural Affairs (DEFRA) is contributing to the protection and restoration of these grasslands through its Environmentally Sensitive Area and Countryside Stewardship schemes. These efforts are hampered by our incomplete understanding of how such meadow systems should be managed hydrologically to maximise the wildlife interest. This report addresses this gap in knowledge, describing a relationship between plant community type and the prevailing soil water regime, which was derived from a field study of species-rich wet grasslands throughout England. The approach used followed that of Project BD0209 (Gowing *et al.*, 1997), which looked at such a relationship on a species by species basis.

1.1 Objectives

1. To quantify the water-regime requirement of plant communities, by interpreting the extensive plant species database currently held at Cranfield University.
2. To analyse the botanical data gathered to date by ADAS under the aegis of the ESA monitoring programme, and to determine those sites which are suitable for hydrological characterisation. To gather further field data from ‘hydrologically-stable’ wet grassland and related habitats.
3. To complete validation of hydrological models on four sites studied under a previous MAFF-sponsored project (BD0209).
4. To assess the effects of a) soil nutrient availability and b) vegetation management regime on community composition in wet-grassland habitat. Then to compare the importance of these effects in comparison with water regime and thus to define the range of grassland plant communities for which water regime would appear to be the dominant environmental factor.
5. To characterise the relationship between the rate of change in the composition of plant communities and the shift in water regime on ‘hydrologically-altered’ sites.
6. To develop appropriate methods for interpreting data and designing monitoring strategies for grassland sites subject to hydrological manipulation.

1.2 Approaches

Field collected botanical data were interpreted in terms of their community type and related to the prevailing water regime at each sampled position, which was described by hydrological models. The project relied on data from a number of sources:

- information previously gathered at a species level was re-interpreted in terms of community type;
- additional existing botanical data from Project BD0209 were utilised once hydrological models for their respective sites had been validated;
- further botanical data were collected from new sites in order to extend the geographical range of the information and to investigate transitional communities;
- sites undergoing hydrological alteration were monitored to generate data on rates of change in plant community composition.

At each site, the botanical composition of the sward was recorded at a large number of spot locations, each of which were mapped for hydrological characterisation. Soil nutrient availability was measured at each site to determine whether it modified the community water-regime tolerances.

2 DATA COLLECTION

2.1 Site selection

Over forty sites throughout England and Wales were visited and 18 selected for further study (Fig. 1; Table 1). Sites were selected based on following criteria:

- Presence of species-rich wet grasslands and transitional communities to other types.
- Availability of existing information on water levels and hydrological management
- Amenable to hydrological modelling, i.e. uniform soil types, well-defined hydrological boundaries.

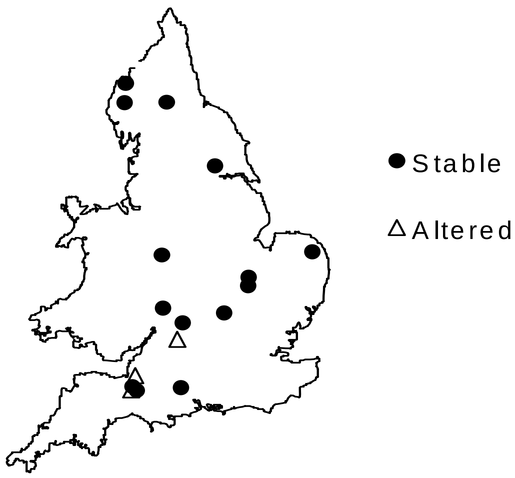

Figure 1 Map showing distribution of sites used in the study. (A list of the rejected sites is given in Appendix A)

Table 1 Location and soil type at each of the selected sites.

Site Name	Grid Reference	Soil Association	Soil type
Belaugh	TG292177	Altcar 2	Fen Peat
Blackthorn	SP632190	Denchworth	Clay
Broaddale	NY255525	Rockcliffe	Clay and sandy loams
Cricklade	SU096958	Thames	Clay loam over sand
Dancing Gate	NY240260	Conway	Silty clay over gravel
East Cottingwith	SE700420	Fladbury 3	Alluvial clay overlying silt
East Harnham	SU151289	Frome	Silt overlying gravelly alluvium
Moorlinch	ST393362	Altcar 1/Midelney	Peaty clay / peat
Mottey Meadows	SJ840134	Wigton Moor	Loamy soils
Nethercote	SP175190	Badsey 1	Clay loam over gravel
Portholme	TL238708	Fladbury 1	Alluvial clay
Southlake	ST364301	Midelney	Alluvial clay overlying peat
Stonygillfoot	NY926263	Ellerbeck	Sandy clay loam over cobbles
Tadham	ST416455	Altcar 1	Fen peat / oligo-fibrous peat
Upton Ham	SO860400	Hollington	Alluvial silty clay loam
Upwood	TL251825	Evesham 3	Clay
West Sedgemoor	ST3522257	Altcar 1	Peaty clay / peat
Wet Moor	ST435245	Midelney	Alluvial clay overlying peat

2.2 Hydrological modelling

Analytical hydrological models were used to simulate water-table behaviour on a fine scale within sites, allowing the location of each botanical sample to be modelled separately. Water-table depth was considered to be the most appropriate hydrological variable in these systems, because it can be interpreted as a surrogate both for root-zone water potential and for degree of soil aeration, when the water table is close to the surface.

At each site, water tables were observed at fortnightly intervals using tubewells. Figure 2 gives a sample of the data collected. Models were validated against these observations (e.g. Figure 3) and then used to simulate water-regimes retrospectively for a period of at least 10 years.

Four generic hydrological models were used

1. The ditch-bounded water-table model (Youngs *et al*, 1989), modified to include surface water (Youngs, 1994), was developed for permeable soils, intersected by water-filled ditches.
2. The shallow aquifer water-table model (Gowing *et al*, 1998) was developed for alluvial soils overlying permeable sand and gravel deposits with hydraulic connection to surrounding rivers. It was modified to incorporate resistance to flow due to soil compaction near the river banks and siltation on the river bed.

3. The water-balance ridge and furrow water-table model (Gowing *et al*, 1998) was originally developed for low permeability clay soils with a ridge and furrow topography, and has been adapted to allow for a range of drainage scenarios.
4. The non-bounded water-table model was developed for situations where the hydrological boundaries of the site were not clearly defined.

These were then tailored to each of the project sites using information on local topography and soil properties. Fuller descriptions of the models are given in Appendix B, a summary of the soil parameters used is in Appendix C and validation plots for each of the model types is in Appendix D.

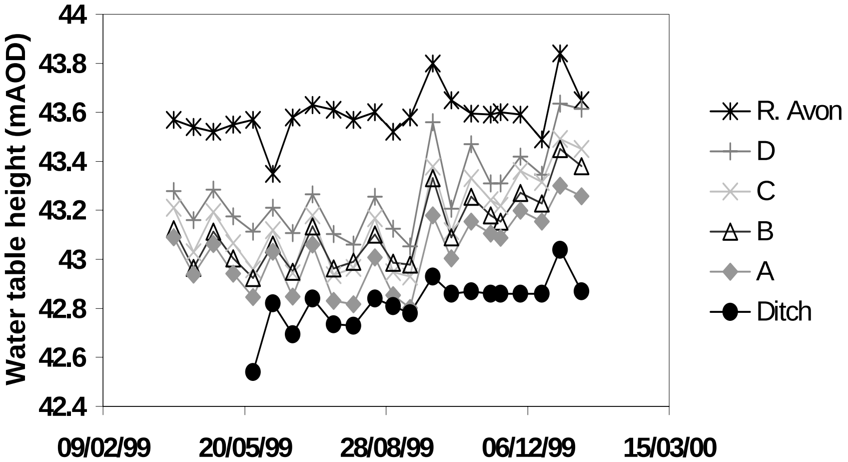

Figure 2. Dipwell data from the East Harnham site on the Hampshire Avon. The 4 dipwells shown formed a transect between the main river and a field ditch. The site's hydrology was largely controlled by these two hydrological boundaries.

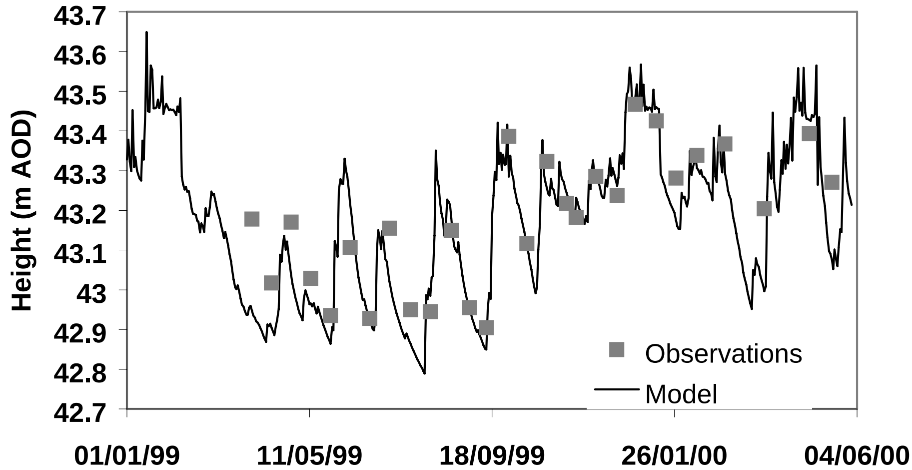

Figure 3 Comparison of the model's output with field observation of water-table elevations at the East Harnham site.

2.2.1 Hydrological interpretation

The output of the models was weekly estimates of water-table elevation at each sampled location over a 10-year period. In order to relate such a mass of raw information with botanical data, it is necessary to summarise it in some form. The method employed is the Sum Exceedence Value (SEV) concept based on earlier Dutch work (Sieben, 1965) and successfully used in project BD0209.

This method relies on threshold depths being specified for each site: one defines the water-table depth at which the zone of densest rooting (taken to be 0-100 mm depth) begins to become waterlogged, the other defines when drying of the surface soil becomes detectable by plants. The waterlogging threshold is calculated from a soil moisture release curve as the depth that gives 10% air-filled porosity. The soil drying threshold is calculated using the Richard's equation (Gardner, 1958) as the depth that gives 0.5 m tension at the surface.

For each threshold, the SEV represents the degree to which water tables exceed it (Figure 4). Waterlogging is only cumulated during the period of active grass growth (March – September inclusive), when the plants are most sensitive to the oxygen status in their root zone. The water regime at a given position is characterised by taking a long-term mean of the annual SEV (waterlogging) and the annual SEV (soil drying).

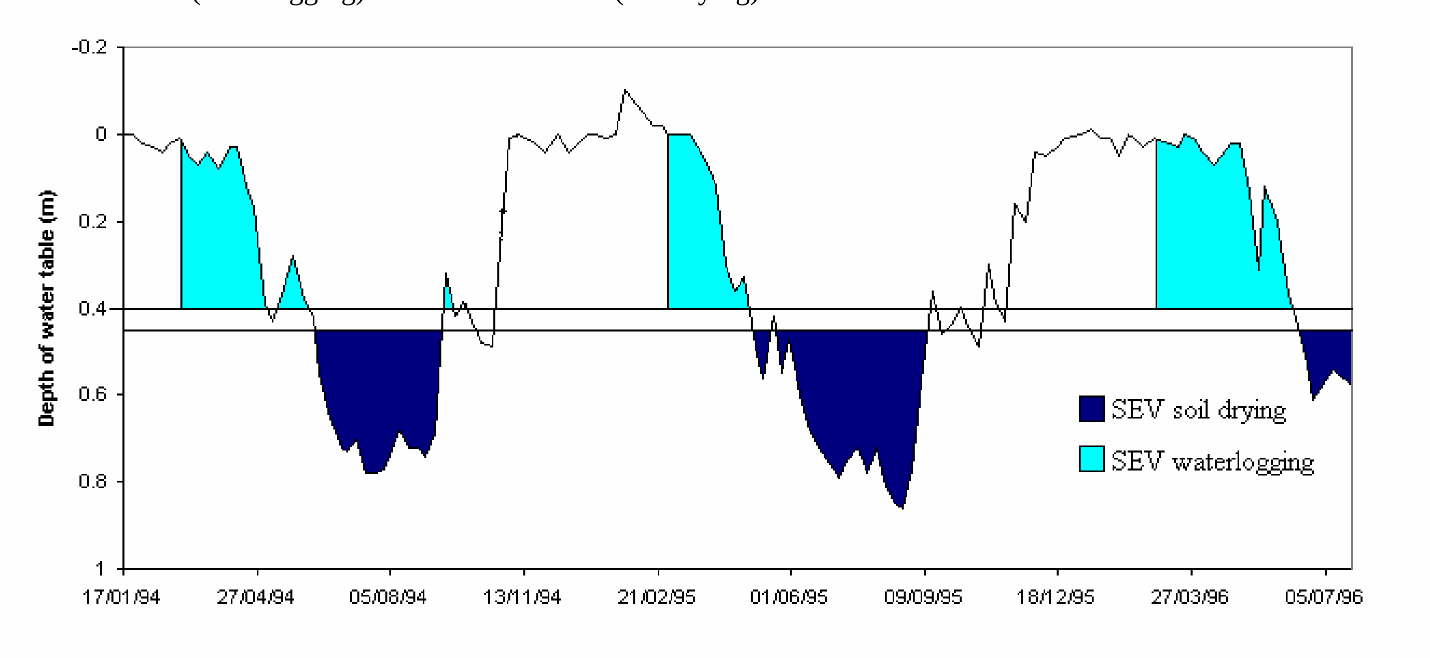

Figure 4. Sum Exceedence Value derivation from a hydrograph as generated by a hydrological model. The horizontal lines represent threshold depths for the particular soil type. The upper one the waterlogging threshold with the shaded area above it representing the SEV(waterlogging), the lower is the soil drying threshold and the shaded area below it represents the SEV(soil drying).

The advantage of using the SEV approach with site-specific thresholds is that the resultant information is transferable between sites. Data from all 20 sites can therefore be combined to show the total spread of water regimes (Figure 5).

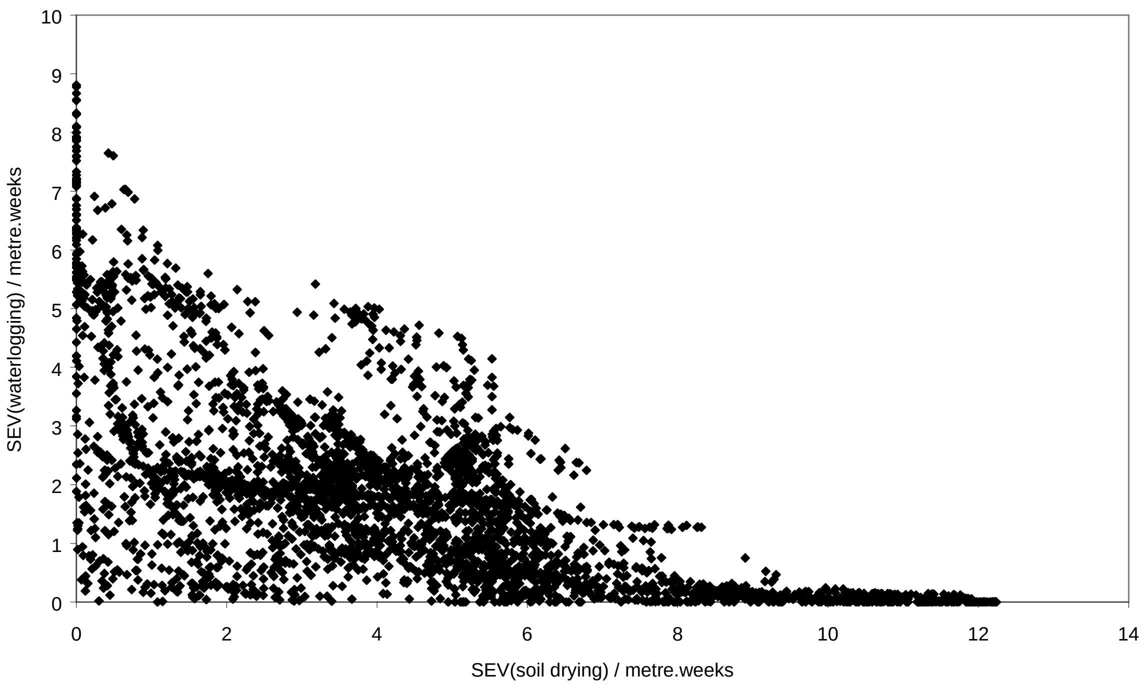

Figure 5. Water regime of all 3750 locations sampled across 20 sites as defined by their two SEVs. Points in the bottom right of the plot represent well-drained, dry soils, whilst those in the top left have almost permanently waterlogged soils. In the bottom left they

have very stable, moderately shallow water tables and in the centre they have fluctuating regimes, typically waterlogged in spring and dry in summer. For a water regime to fall in the extreme top right corner is not physically possible.

For each of the points in figure 5, botanical data are available. In project BD0209, species preferences were derived by analysing the relative frequency of a species across the range of water regimes (e.g. Figure 6). The data set presented by Gowing *et al.* (1997) has been updated to include the new data set of 3750 points. (Appendix E)

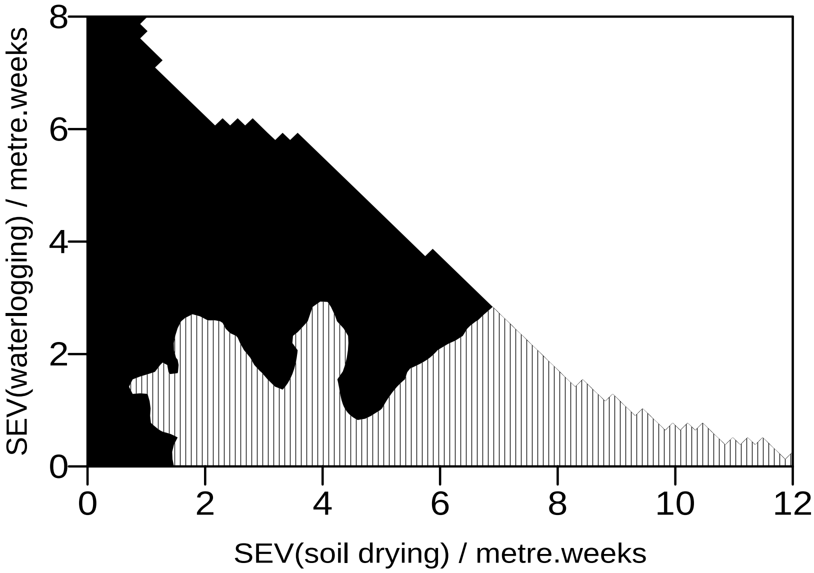

Figure 6. The preferred water-regime zone of the creeping bent-grass (*Agrostis stolonifera*). The dark region represents the range of water regimes in which the species occurs significantly ($P<0.05$) more often than by chance**.**

2.3 Soil nutrients

To investigate the effect of nutrient availability on the water-regime tolerances of vegetation, a total of 155 samples from the project sites were analysed for pH, available phosphorus, available potassium and total-nitrogen. Standard methodologies were used (Appendix F) and the results are presented in Appendix G. Ten of the fourteen plant communities identified by the project were sampled for soil nutrient content. Mean values were calculated by site and by community type for each of four determinands (pH, available phosphorus, soluble potassium and total nitrogen.)

2.4 Botanical data

All new sites were surveyed during the lifetime of project (1998-2001); and all during the period mid-May to early-July. Quadrats measuring 1m × 1m were used and all plant species were recorded with an estimate of their cover. A total of 3904 botanical samples were recorded. (This slightly exceeds the number of hydrologically modelled positions because the model for one site, East Cottingwith, was not successfully validated during the project due to observations being curtailed by Foot and Mouth access restrictions. The botanical data from that site was therefore not used in determination of the hydrological relationships.) For each of the sampled quadrats, the mean Ellengerg F-value (moisture score; Hill *et al*., 1999) was determined from the values assigned to each of the component species.

3 PLANT COMMUNITY CLASSIFICATION

Data from all 3904 quadrats were analysed using Two-Way INdicator Species ANalysis (TWINSPAN) to identify groups of quadrats that were similar to one another (hereafter referred to as “End Groups”.) Fourteen major End Groups were identified and each was regarded as representing a separate community type. Twelve of the groups were considered as mesotrophic grasslands as defined by the National Vegetation Classification (Rodwell, 1991), whilst the remaining two were better described as swamps (fens). Brief descriptions of each of the end groups are presented in Table 2. Fuller descriptions and synoptic tables for each community are presented in Appendices H and I respectively.

Table 2 Brief descriptions of each of the 14 end groups generated by TWINSPAN analysis.

Twinspan Endgroup	**Alliance**	**NVC type** or code	**Community Name**	**Number of samples**
1	Polygano-Trisetion	MG3	*Anthoxanthum odoratum – Geranium sylvaticum* grassland	108
2	Cynosurion	MG4	*Alopecurus pratensis – Sanguisorba officinalis* grassland	758
3		MG5a	*Centaurea nigra –Cynosurus cristatus* grassland, *Lathyrus pratensis* sub-community	113
4		MG4+	*Alopecurus pratensis – Sanguisorba officinalis* grassland species-poor variant	730
5		MG5b*	*Centaurea nigra –Cynosurus cristatus* grassland *Hordeum secalinum* variant	73
6		MG6b’	*Lolium perenne – Cynosurus cristatus* grassland *Filipendula ulmaria* variant	500
7		MG7C#	*Lolium perenne – Alopecurus pratensis – Festuca pratensis* grassland species-rich variant	127
8	Calthion	MG8	*Cynosurus cristatus – Caltha palustris* grassland	118
9		MG8 *Cx*	*Cynosurus cristatus – Caltha palustris* grassland *Carex* spp variant	679
10		*Ag/Cx C. distans*	*Agrostis/Carex* grassland *Carex distans* variant	61
11		*Ag/Cx*	*Agrostis/Carex* grassland	345
12	Potentillion	MG13	*Agrostis stolonifera – Alopecurus geniculatus* grassland *Alopecurus pratensis* variant	233
13	Phragmition	S24	*Phragmites australis – Peucedanum palustre* tall-herb fen	22
14		S25	*Phragmites australis – Eupatorium cannabinum* tall-herb fen	37

The variants labelled MG4+, MG5b*, MG6b’, MG7C#, MG8*Cx* and the community denoted as *Ag-Cx* are not defined in the published NVC. In addition the community labelled as MG13 is treated as a single entity in this report, which reflects the use of this term by practitioners, but there are phytosociological grounds for splitting the group in two and reclassifying the parts (see appendix H for a discussion.)

Appendix J details the occurrence of each of the above end groups by site and provides a key for determining which of the communities may be present on sites for which no NVC map is available.

4 PLANT COMMUNITY WATER-REGIMES

The SEV(waterlogging) and SEV(soil drying) variables were calculated for 3750 quadrats. The SEVs were based on a 5-year mean. Discrimination analysis showed 5-year means to have the greatest explanatory power and previous ecohydrological studies have also used this period to describe water regimes (Noest, 1994). The mean and its 95% confidence interval for each of the above community types are shown in Figure 6. Each community has a significantly ($P<0.05$) different water regime requirement to that of its neighbours.

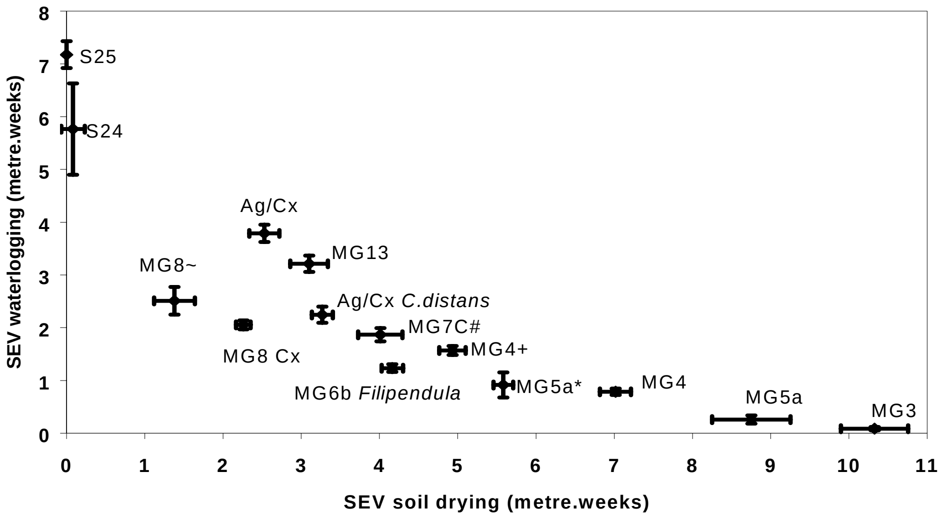

Figure 6: Water-regime of each community type expressed as the mean and 95% confidence interval of the mean on each axis. Error bars are plotted symmetrically, assuming samples are normally distributed, which was not always the case. Differences between means were tested using Tukey pairwise comparisons.

Logistic regression analysis was carried out to reveal the community response to the SEV environmental variables (Figure 7 and Figure 8). SEV soil drying for MG4 shows a maximum at 9.9 suggesting it is not favoured by the very dry conditions that suit MG5a (Figure 7).

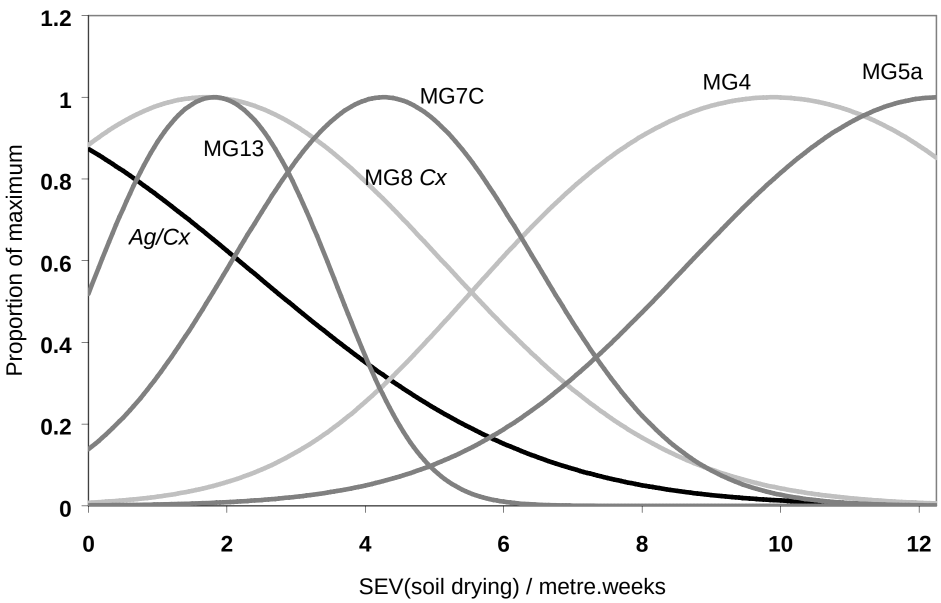

Figure 7 Logistic regression of community response to the SEV(soil drying) axis. Gaussian curves were fitted to presence/absence data for a range of community types, showing their different tolerances to soil drying..

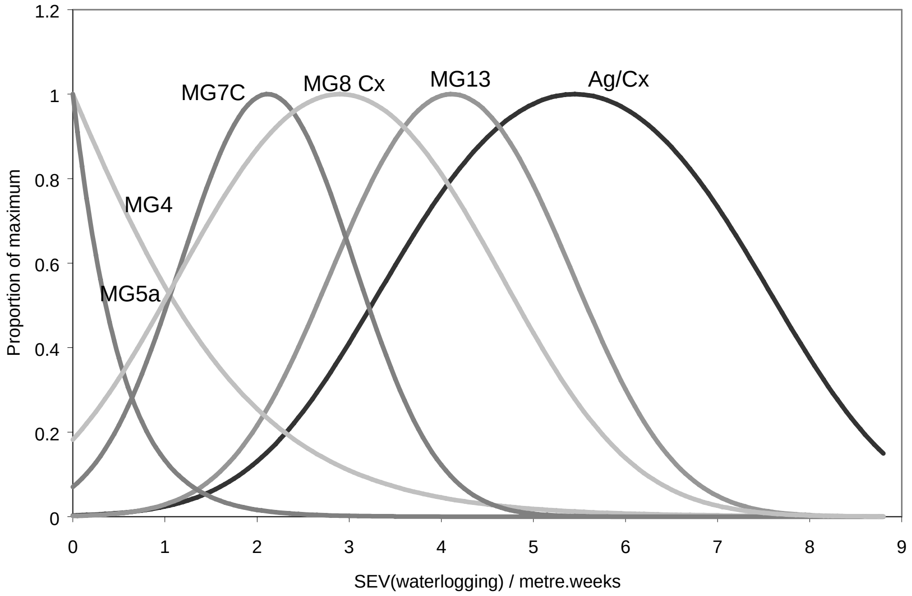

Figure 8 Logistic regression of communities against SEV(waterlogging) axis, illustrating the differetial tolerances of a range of community types**.**

In order to visualise the range of water regimes preferred by each community type, as was done for species in Figure 6, similar plots have been constructed for each of the communities listed in Table 3. The plot for MG4 grassland (Figure 9) is given as an example. The plots for other communities are presented in Appendix K.

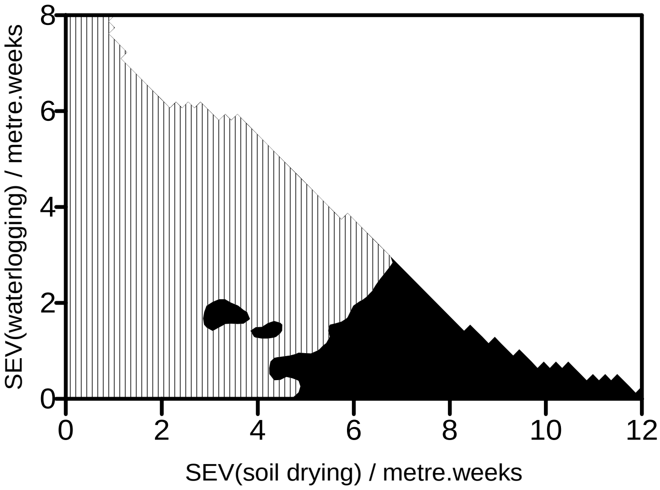

Figure 9. The preferred water-regime zone of the floodplain meadow community (MG4). The dark region represents the range of water regimes in which the species occurs significantly (P<0.05) more often than by chance**.**

A comparison between the mean Ellenberg F-value and the SEV(waterlogging) for each quadrat is shown in Figure 10. The strong relationship between the two variables suggests that Ellenberg scores may be used as a surrogate for SEV(waterlogging) over this range of water regimes, when hydrological modelling of a site is unpracticable.

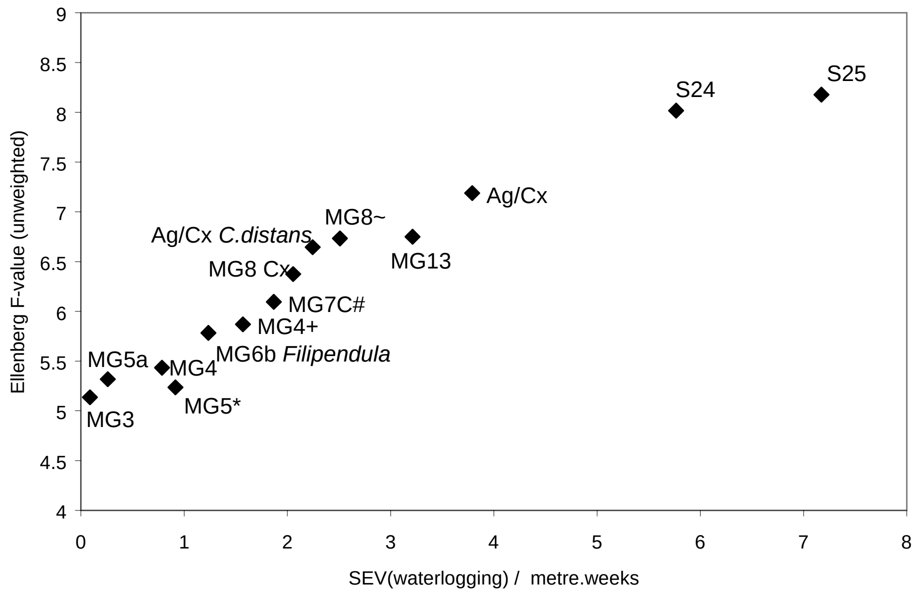

Figure 10. Mean Ellenberg F-values derived from published values for each of the species listed in the end group generated by TWINSPAN analysis plotted against the mean SEV(waterlogging) for the same community.

The soil samples taken during field surveys were classified according to which community they supported (Appendix G). The availability of phosphorus in each of them was measured using the Olsen extraction method, which has been shown to be the most appropriate one for mixed species grasslands (Gilbert, 2000.) The results are presented in Figure 11. There are significant differences between community types showing that soils differ not only in water regime, but in nutrient availability too. Phosphorus availability was the only measured soil variable that showed a clear pattern with respect to ommunity type. An analysis of soil nutrient status by site and by community type is tabulated in Appendix G.

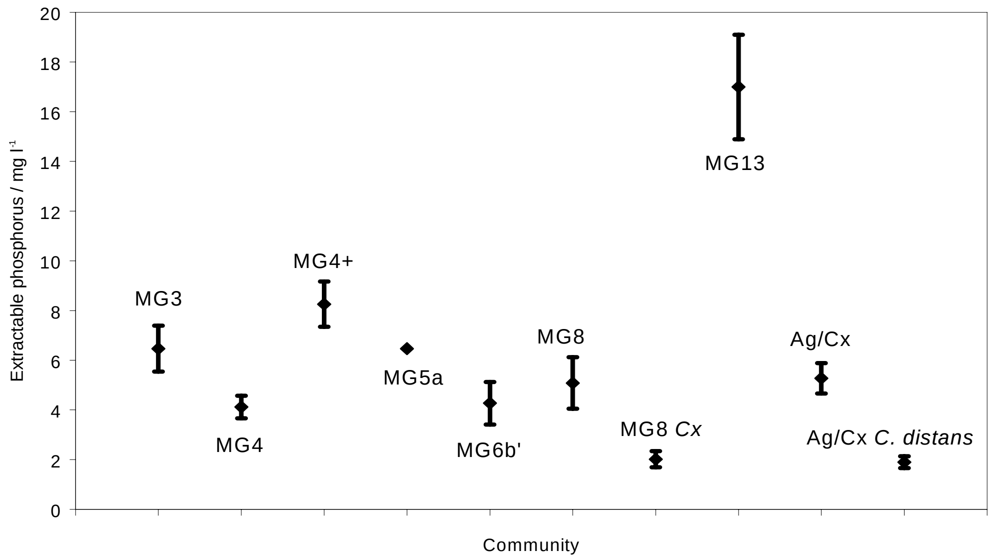

Figure 11 Phosphorus availability in top 150 mm soil under each of the main communities investigated. Mean ± S.E.

Ordination of the botanical data using detrended correspondence analysis (DCA) suggested that water regime was the dominant environmental variable with soil phosphorus availability showing a subordinate role. See Appendix L for ordination plots. Figure L4 demonstrates that phosphorus availability may be a component of the second strongest axis of variation within the botanical data. Although soil potassium content differed significantly between some community types, it did not correlate strongly with any of the major ordination axes and is therefore assumed not to be a driving variable across the range of soils studied. One noticeable factor was that sites with high concentrations of soil phosphorus (and potassium) were ones experiencing regular river flooding (Cricklade, Upton, Portholme.) Within these sites there was often a clear pattern of phosphorus availability with the nutrient most available in depressions that trapped flood waters and therefore presumably receive the largest amounts of flood-deposited silt..

Due to interactions such as this, phosphorus availability was found to correlate strongly with water regime on many sites and the independent effects of the two factors on community composition could not be discriminated. As a result, it was not possible to test adequately the hypothesis that the water-regime tolerances of communities became less exacting as nutrient availability increased using the observed data. Manipulative experiments would be need to address this question rigorously.

There was no discernible correlation between botanical composition and vegetation management in terms of whether hay was cut each year or whether cattle were turned out in July without cutting the hay. It is possible that the cessation of regular hay cutting at many of the uncut sites has been too recent yet to reveal itself in the community composition.

5 VEGETATION CHANGE IN RESPONSE TO ALTERED HYDROLOGY

At three sites, it was possible to follow the change in plant community composition in response to a managed hydrological change. A further three sites were selected as part of this study, but were reliant on external agencies to implement the change, which did not occur in time for results to be presented here. The three sites used formed part of the "stable site" analysis above, but data collected after the change in hydrology were not used in that study.

The approach taken at these sites was to use annually-recorded, permanent quadrats to follow the rate of change in community composition. To study subtle changes in community type, the 14 communities listed in Table 3 were considered too broad and therefore botanical data from each of the three sites was independently subjected to TWINSPAN analysis to characterise the plant communities occurring within a particular site.

5.1 Cricklade North Meadow NNR.

North Meadow is a classic example of floodplain meadow (MG4) vegetation. However, other communities do occur within it; primarily in topographic depressions, which retain floodwaters. The hydrology of part of the site was deliberately altered in 1999, under this project, such that retained flood water would be released back to the adjacent River Thames via a culvert. The intention was that the degree of waterlogging over part of the field be reduced. Under such conditions, the model presented here would predict that the MG4 meadow community would colonise the depressions from which it had been excluded by inundation communities (e.g. MG13). To check that any changes in plant community were indeed due to the hydrological alteration rather than other influences a control area, unaffected by the new culvert but having a similar spectrum of community types was also recorded.

Unfortunately, it was not possible to test the prediction due to the exceptional weather during the period 1999-2001, which was the wettest 36-month period on record. Both Spring 2000 and Spring 2001 saw exceptionally heavy rainfall in the Thames Valley, resulting in sustained high river levels submerging the culvert and preventing the planned drainage during the critical months at the start of the growing period. Nevertheless the community composition did change in response to this change in hydrological conditions albeit in the opposite direction to the one proposed.

At Cricklade, botanical data were collected from 180 permanent quadrats over 4 growing seasons (1998-2001). All these data were subjected to TWINSPAN analysis with the result that 13 discrete End Groups were defined (see Appendix M for synoptic tables and community descriptions and Table 3 for a general interpretation of the End Groups in terms of the NVC). These Groups were ranked in terms of their botanical similarity using an ordination technique (DCA,) which defined the main axis of variation within the botanical data and ordered all the individual samples along this axis. Figure 12 shows the position of each End Group on a plot of waterlogging against this main axis of botanical variation. For each of the 13 End Groups, the range over which they predominantly occur is represented by an oval ring. The plot shows a strong positive correlation between the two variables suggesting that waterlogging is one of the main drivers in plant community composition at the site.

Overlain over this series of rings is the relative position of the individual quadrats as they occurred in 1998 and again in 2001. One can see a general move away from End Groups 1-4 and toward End Groups 10-13. End Groups numbered 2 and 3 would fall under the umbrella of the MG4 floodplain meadow as defined by the NVC, whilst those numbered 10 and 11 would be similar to the NVC description for MG13 inundation grassland. Figure 13 shows the same data but at higher resolution and tracks just one cohort of 37 quadrats – all those that were classified as End Group 2 (i.e. MG4) in 1998. By 2002, only 2 of the 37 remain in the original End Group – the rest have shifted toward wetter community types. Therefore the data show a dramatic change in community type over just 3 years. MG4 grassland has retreated considerably whilst swamp communities have expanded (Figure 14). All as a result of three high rainfall years – not as a product of deliberate manipulation. This illustrates the dynamism of plant communities in floodplain grassland. What would be of great interest to those concerned with nature conservation is whether the MG4 community can re-colonise the area it has lost once drainage conditions improve and how quickly this process can occur.

Table 3. Allocation of botanical End Groups at Cricklade North Meadow NNR to the nearest community as defined by the NVC. (Community variant codes as for Table 2.)

End Group	NVC type	End Group	NVC type	End Group	NVC type
1	MG5	6	MG7C#	11	*Ag/Cx*
2	MG4	7	MG13	12	A10
3	MG4	8	OV28	13	S19
4	MG4+	9	OV28		
5	MG4+	10	*Ag/Cx*		

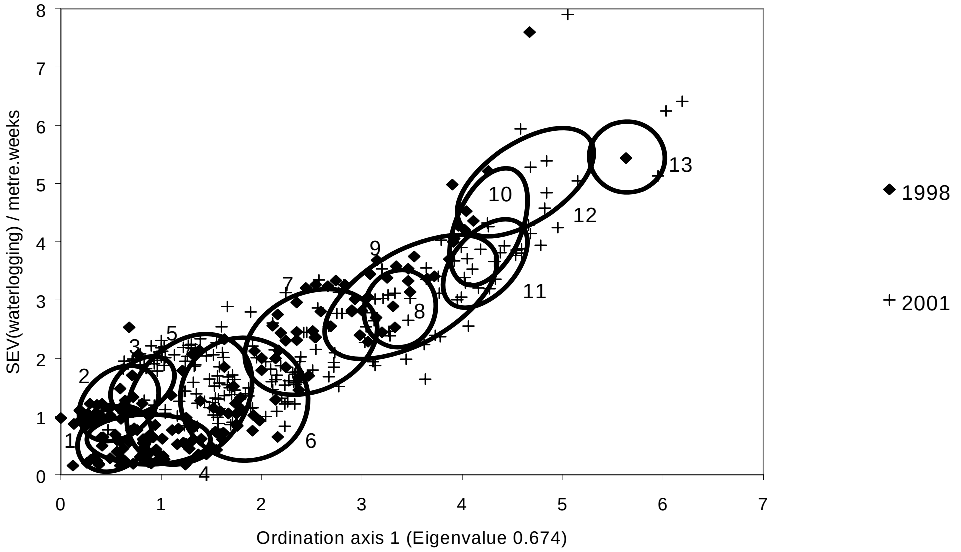

Figure 12 The core water regime ranges of the 13 grassland communities defined from the permanent quadrats at Cricklade North Meadow NNR. Ranges are denoted by numbered oval rings. The numbers corresponding to community descriptions in Appendix M. Overlain on these ranges are the individual quadrats for the years 1998 and 2001.

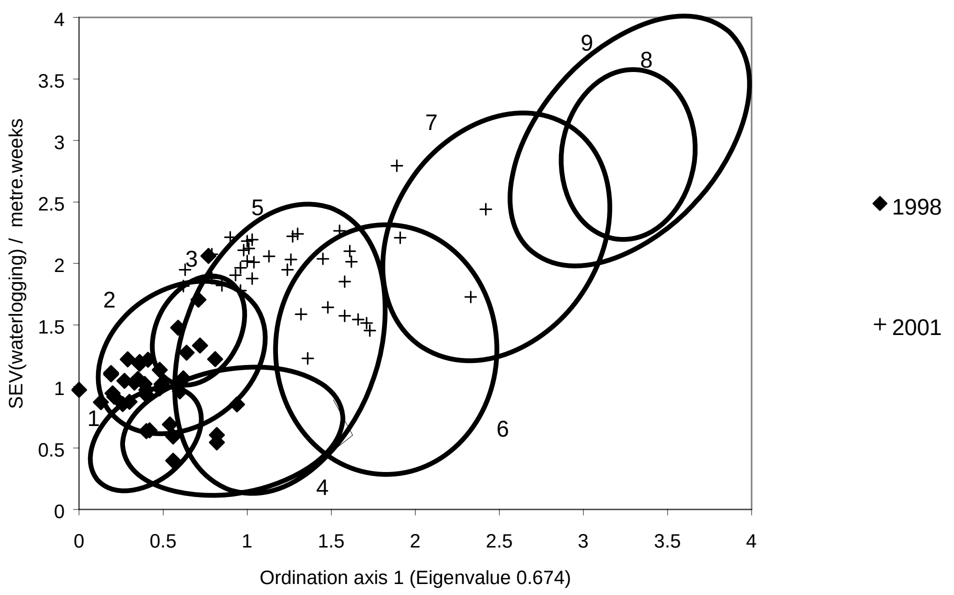

Figure 13 Changes in community type experienced by quadrat locations in Cricklade North Meadow NNR that were classified as End Group 2 (MG4) in 1998 (see Table 4 for key to numbers**)**

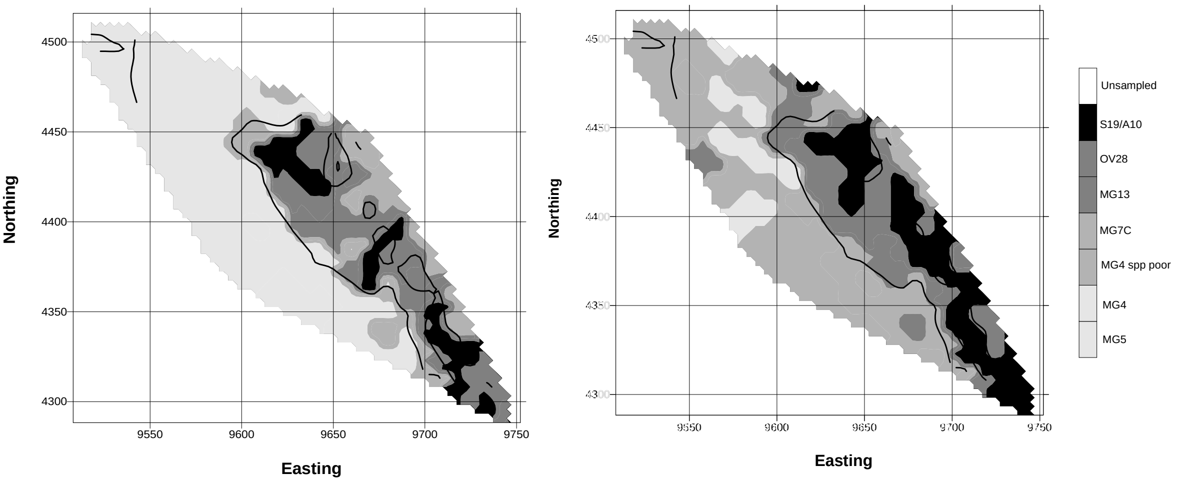

Figure 14 Maps of plant community distribution, within the drainage basin at Cricklade North Meadow NNR that is affected by the new culvert, on the left is the situation in 1998 and on the right in 2001. Shading denotes community type and black lines represent contours at 0.2 m spacing.

Figure 14 demonstrates that within one of the intensively studied areas of Cricklade North Meadow NNR, the MG4 community, for which the site is designated as a candidate Special Area for Conservation (cSAC) at a European level, has all but disappeared within 3 years. The control area showed a similar trend indicating that the culvert itself was not a factor in the hydrological change. The possibility of the area being recolonised by MG4 once drainage conditions improve is in some question because our soil nutrient data suggest phosphorus availability in the area has increased above the normal range found under MG4 as a result of flood-deposited sediments.
The botanical data for the site were also analysed at a species level. Fitting logistic regression lines to describe their response to increased waterlogging is shown in Figure 15.

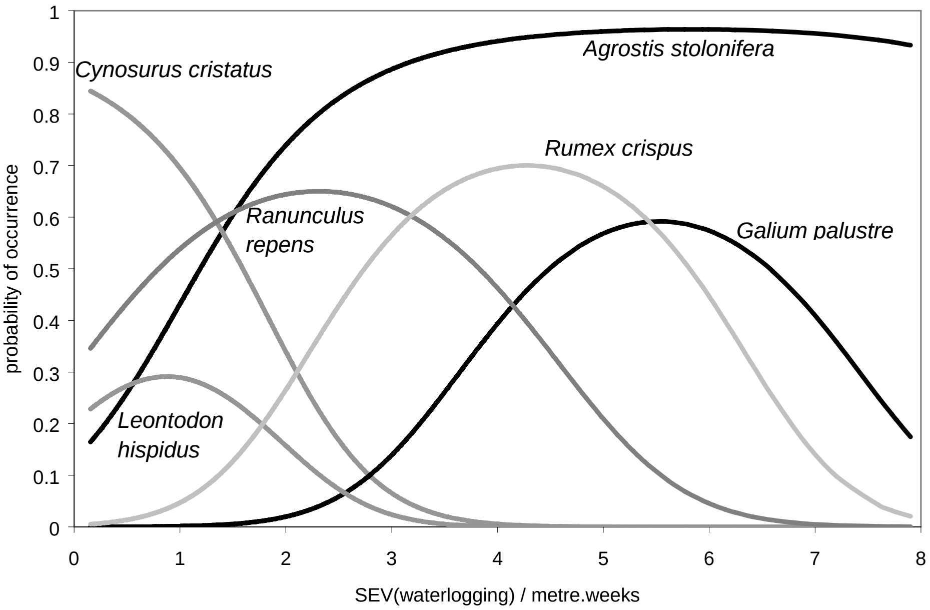

Figure 15 Species response to SEV(waterlogging) at Cricklade North Meadow NNR as derived from logistic regression analysis

5.2 West Sedgemoor SSSI

Two fields within the RSPB reserve were studied as altered sites because baseline data were available from 1993 prior to an inadvertent change to the hydrological regime as a result of ditch slubbings creating a bund around each of the fields in 1994 allowing surface water to pond. When the effect of this additional waterlogging on the vegetation was observed, the bunds were broken in 1996 to allow surface water to drain once more. The hydrological model for the site was calibrated

to take account of these changes. Figure 16 shows the result of the increased waterlogging on the plant communities in the two fields. The bulk of the changes occurred within a year of the bunds being created. There is evidence of stabilisation since the bunds were broken and some reversion toward better-drained vegetation types, but this is evident in less than 10% of the samples.
The approach to data interpretation was the same as that for Cricklade described above. Figure 16 shows a wholesale change in plant community type in response to a change in the site's hydrological management. The great majority of the points were classified as End Group 1 (MG8, the species-rich water meadow) in 1993, but as End Group 6 (*Agrostis/Carex* inundation grassland) in 2001.

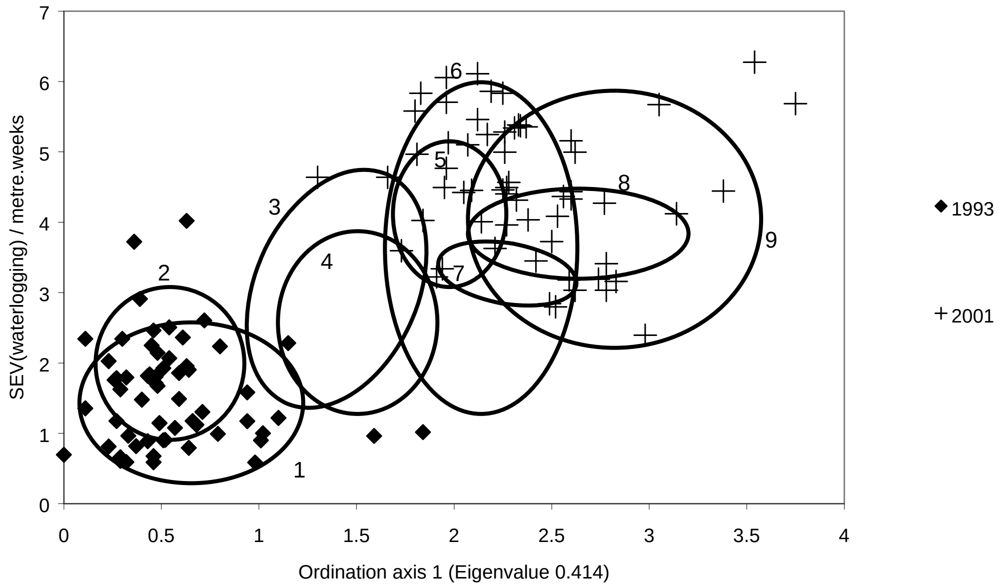

Figure 16 Movement in community type within two fields within the West Sedgemoor SSSI. Rings represent the ranges of the End Groups (which are described in detail within Appendix O and summarised in Table 4). Symbols represent individual quadrat samples in the baseline year 1993 and the most recent survey in 2001.

Table 4 Allocation of botanical End Groups at West Sedgemoor to the nearest community as defined by the NVC. (Community variant codes as for Table 2.)

End Group	NVC type	End Group	NVC type	End Group	NVC type
1	MG8	4	MG8/*Ag-Cx*	7	*Ag-Cx*
2	MG8	5	*Ag-Cx*	8	*Ag-Cx*
3	MG8/*Ag-Cx*	6	*Ag-Cx*	9	OV28

The pattern of movement from year to year is shown in Figure 17, which focuses on a single field (RSPB field no 1412) and displays results from all 6 surveys that were conducted there. The hydrological data shows the waterlogging to become increasing intense through time and the movement along the axis of botanical variation reflects this. As at Cricklade, the degree of waterlogging in the growing season appears to dominate the pattern of community change. The increase in water logging between 1993, 1994 and 1995 is believed to be a result of management, the continued increased wetness in 2000 and 2001 is a result of the prevailing weather, which was particularly wet in those springs. It should be remembered that the SEV(waterlogging) value reflects the mean situation over the 5 preceding years. There is little evidence for a reversal in the trend following ameliorating management, though conditions were relatively stable between 1998 and 2000 when a few quadrats did show signs of recovery. The hope of following the trajectory of that recovery was dashed by the extreme wet conditions in 2000-2001.

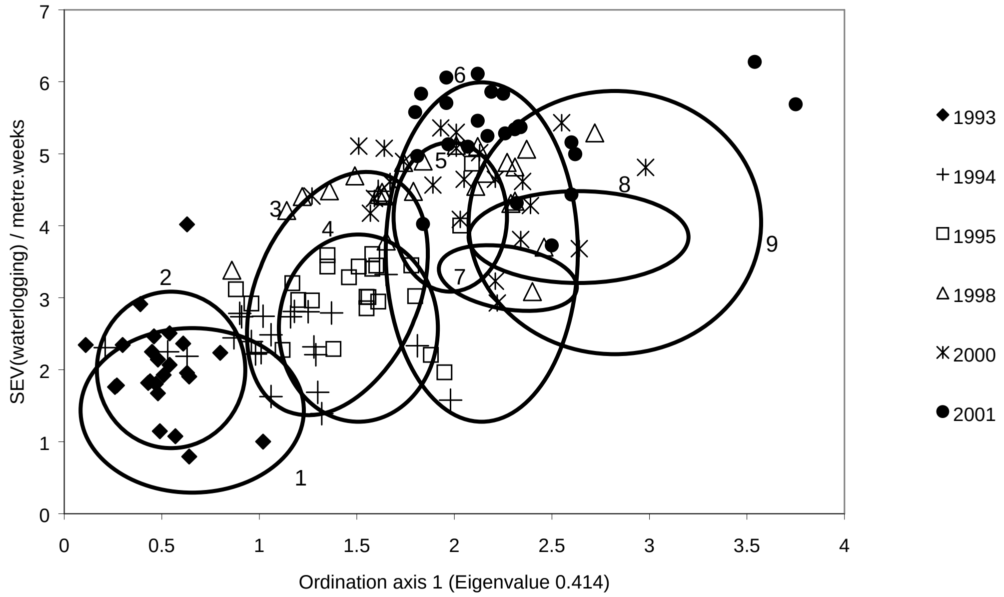

Figure 17 Changes in plant community composition within West Sedgemoor field number 1412. Symbols represent individual quadrat samples in each of the 6 survey years. The rings denote the ranges of the various End Groups as for Fig 15.

5.3 Tadham Moor Experimental site.

Tadham Moor was studied as an altered site due to the availability of annual botanical data from revisited locations (courtesy of Owen Mountford, CEH). The site underwent a change of hydrological management in the winter of 1994/1995, when water levels in some ditches were raised to bank-full during November-April. However these raised levels were not held consistently until 1996, due to technical difficulties. The waterlogging of the site has further increased during the period 1999-2001 due to high rainfall. Figure 18 shows the overall effect of the changes between 1994 and 2001. Only locations within the "control" area of a preceding nitrogen application trial were used to avoid the complication of different plot histories.

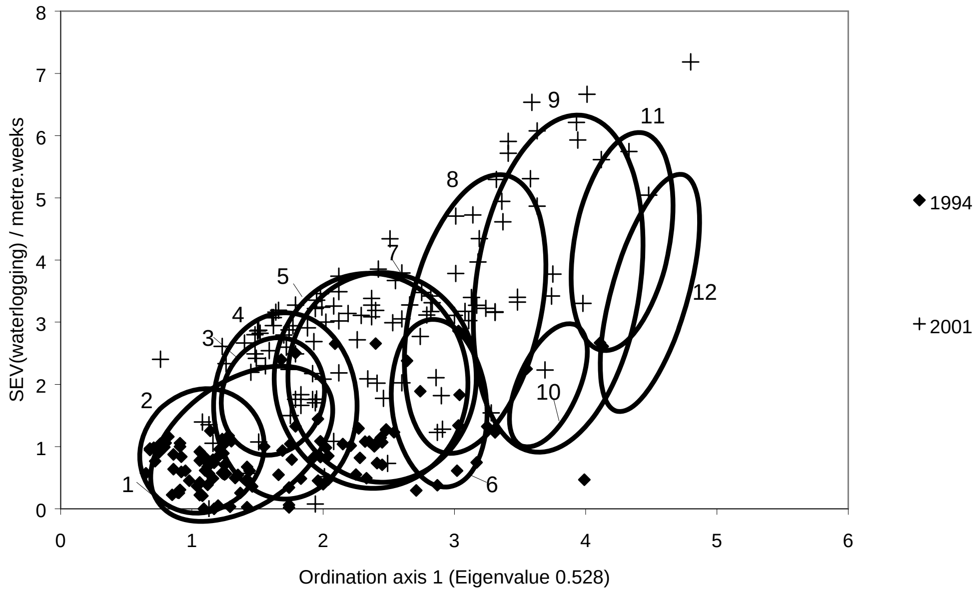

Figure 18 Movement in community type within the control fields at Tadham Moor. Rings represent the ranges of the End Groups (which are described in detail within Appendix P and summarised in Table 5). Symbols represent individual quadrat samples in the baseline year 1994 and the most recent survey , 2001.

Table 5. Allocation of botanical End Groups at Tadham Moor to the nearest community as defined by the NVC. (Community variant codes as for Table 3.)

End Group	NVC type	End Group	NVC type	End Group	NVC type
1	MG6b’	5	MG6b’/*Ag-Cx*	9	*Ag-Cx*
2	MG6b’	6	MG6b’/*Ag-Cx*	10	OV28
3	MG6b’	7	*Ag-Cx*	11	S19
4	MG6b’/*Ag-Cx*	8	*Ag-Cx*	12	MG13

Although the change in plant communities at Tadham is not as dramatic as at the other two sites, following a single group over the 7 years, changes are more distinct. Figure 19 shows the changes in the 56 quadrats that started in End Group 3 (MG6b *Filipendula* variant), but changed into transitional stands and eventually into clear examples of the *Agrostis*-*Carex* community. At this site too, degree of waterlogging appears to be driving community change.

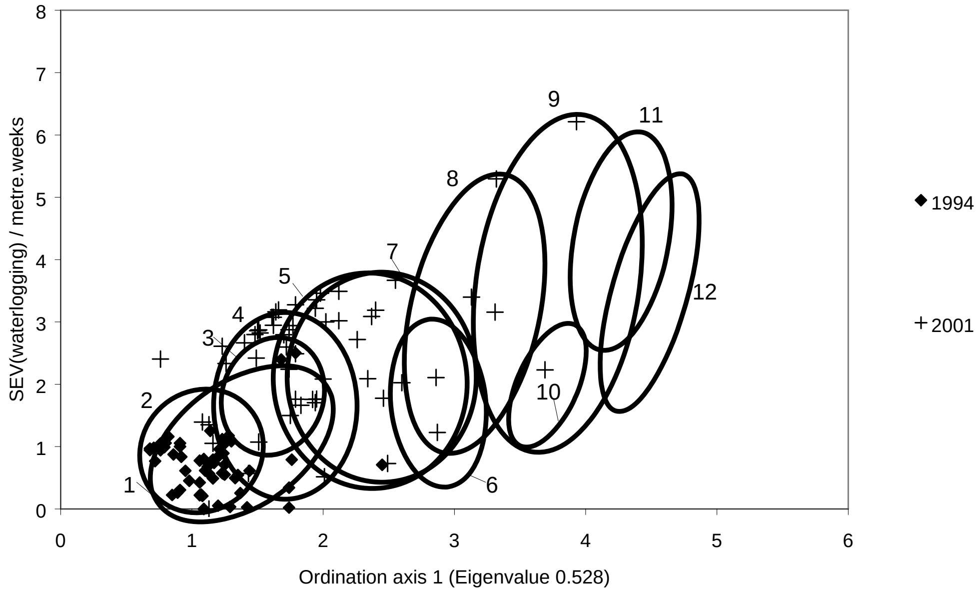

Figure 19 Community change at Tadham Moor showing the fate of quadrats that were representative of a well drained sward but has gradually become an inundation grassland.

6 DISCUSSION

The results have demonstrated that it is possible to quantify the water-regime requirements of plant communities in a way that is transferable between sites. The data presented relate to traditionally-managed, neutral, mesotrophic grasslands on moderately permeable soils (hydraulic conductivities of 0.1 m d^{-1} or higher.) Extrapolation of the results to other types of grassland, other vegetation types or other soil types should be done with care.

Information was gathered on all the major grassland communities of conservation interest found on river floodplains in England and Wales. Each of these was shown to have a distinct water regime when their means were compared. The restoration of any floodplain grassland should therefore fully consider the water regime of the site, as this will often be the major determinant of the ultimate botanical composition of the sward.

Monitoring of sites subjected to an alteration in hydrological management demonstrated that changes in community type can be rapid in response to increased waterlogging. The actual rate of change depends on the magnitude of the hydrological alteration. Many communities changed in character after a single season with enhanced waterlogging, while others changed gradually over a period of 3-4 years. It is important to determine the rate at which such communities might recover when the waterlogging is relieved. Continued monitoring at some of the project sites should reveal this information.

The survey of soil phosphorus and potassium concentrations, indicated that sites receiving floods from major rivers gave the highest values. This supports the assumption that flood-deposited silts are a major source of plant nutrients on floodplains. Such natural mechanisms of nutrient supply are necessary to maintain mesotrophic conditions, but excess deposition may lead to an alteration in community composition and apparently a reduction in species-richness. Manipulative experiments are required to confirm this inference and to address the original questiuon of to what extent enhanced nutrient availability alters the tolerance of plant communities to the soil’s water regime.

Of the original objectives, the first four have been fully met. Objectives 5 and 6 have only been partially completed because of a lack of data relating to sites on which waterlogging decreased over the period of the project. This omission was primarily due to the extremely high rainfall during 1999-2001. The wettest 36-month period ever recorded. Swollen rivers prevented some sites from draining during spring, thereby disabling our experimental work. Access restrictions introduced as a result of Foot and Mouth Disease and the postponing of hydrological management schemes by external agencies also limited our data collection. Further data collection at some experimental sites combined with more normal rainfall patterns, such as has occurred in 2002, will allow these outstanding objectives to be met in full.
Further research in this area should focus on the interaction between the soil water regime, which has been shown to be the major driver of plant community composition in these systems, and nutrient availability which is reputed to be an important modifier of community tolerances and may underlie the mechanism governing species' tolerances to the soil water regime.

7 POLICY IMPLICATIONS

The results of this project have re-inforced conclusions from earlier reports (Gowing, 1996, Gowing *et al*, 1997), which indicated the botanical composition of wet grasslands was primarily determined by the degree of waterlogging experienced in the growing season. This project has shown community type to be sensitive to waterlogging and furthermore that the tolerance of individual communities are distinct and can be quantified. As a general rule the species-rich grassland communities (MG3, MG4, MG5, MG8) are intolerant of waterlogging, whilst the most tolerant grassland communities (MG13, OV28, *Agrostis-Carex*) tend to be species-poor. The policy implication of this finding is that management prescriptions for environmental land management schemes involving species-rich grassland should consider specifying a maximum water level to limit the degree of surface flooding, in addition to the current minimum level specification. Furthermore, there should be some positive encouragement of managers to maintain surface drainage and water distribution systems. Future refinement of water-level prescriptions under the periodic ESA review process, could be tested against the information generated by this project, in order to predict the effect on grassland community composition.
Availability of phosphorus in the soil does affect community composition, but over the range of communities within this study (neutral, wet, mesotrophic grasslands) the influence was much weaker than that of water regime and not independent from it. The availability of phosphorus therefore does need to be considered when selecting sites for restoration of species rich grassland, but in the context of the prevailing water regime. The impact of sediment deposition by floodwater should also be considered in the design of hydrologically managed schemes.
Comparison of mean Ellenberg scores against the quantitative data derived from hydrological modelling suggests that these qualitative indices could be used as a surrogate for the SEV (waterlogging) parameter over the range of water-regimes experienced by wet grassland. Such an approach may form the basis of a tool with which Project officers could analyse data from botanical surveys in order to determine the effect of water regime on the plant community.

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9 ACKNOWLEDGEMENTS

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Appendix A

Hydrologically stable sites for consideration (BD1310)

Site Name	Location	NGR	Size	Status	Site and community description	Soil Association	Geology	Soil
Acaster South Ings	North Yorkshire	SE594437	37 ha	SSSI	Two meadows adjacent to the River Ouse, with topographic variation. MG4	Fladbury 3	River alluvium	Clayey, fine silty and fine loamy soils affected by groundwater.
Askrigg Bottoms	North Yorkshire	SD948903	2.8 ha	SSSI	Meadow adjacent to River Ure, managed for hay cropping. MG3b	Enborne	River alluvium	Deep fine loamy and Clayey soil. Variably affected by groundwater.
Aubert Ings	North Yorkshire	SE453538	9.6 ha	SSSI/NNR	Meadow within meander of the River Nidd. MG4 MG5	Wharfe	River alluvium	Deep permeable fine loamy soils. Some similar soils variably affected by groundwater.
Breighton Meadows	North Yorkshire / Humberside	SE704330	26 ha	SSSI/NNR/ SACetc.	MG4 MG8	Fladbury 3 Newport 1 (East of river)	River alluvium Glaciofluvial drift	Clayey, fine silty and fine loamy soils affected by groundwater. Deep well drained sandy and coarse loamy soils.
Burley Dene	Worcestershire	SO814325	17 ha	just notified as SSSI	MG4 flood meadow vegetation			
Burnfield Meadow, Leckford	Hampshire	SU379386	6.0 ha	Test Valley ESA	Old Water Meadow adjacent to River Test			
Cassington Meadows	Oxfordshire	SP463101	7 ha	SSSI/SAC UTT ESA	Two meadows adjacent to the River Thames.	Thames	River alluvium	Mainly calcareous clayey soil affected by groundwater.

Site Name	Vegetation Survey NVC communities	Vegetation Management	Water Level Management Plan	Hydrological Change	Soil Profile
Acaster South Ings	Northern meadow seems drier, dominated by MG4. Transitional vegetation appears in the damper southern meadow, which is less species-rich. MG1e, MG4, MG4/8, MG4/7C, MG7C and OV28a represented.	Both meadows appear to be well managed in the traditional fashion.	Unknown	No evidence of change. Drainage ditch dividing the two meadow and back ditch appear intact.	Northern Field - Clayey silt 0-120cm +. Southern Field - Silty clay, predominately clay 0-100cm +.
Askrigg Bottoms	MG3 vegetation with *Cirsium helenoides* , *Geranium sylvacticum* common, aswell as *Alchemilla filicaulis* , *Stachys officinalis* and *Sanguisorba officinalis* present.	Appears to be well managed - cut after-math grazed.	Unknown	Hydrology controlled by rainfall, over topping from river and possibly seepage from surrounding area.	Soil quite deep > 120cm and very sandy. Loamy sand between 90 and 120cm deep.
Aubert Ings	Atypical vegetation with *Hyacinthoides non-scripta* and *Anemone nemoralis* frequent components. Species-rich site.	*Heracleum sphondylium* present occasionally suggesting infrequent or late cutting management	Unknown	Hydrology controlled by rainfall with some seepage from the river	Clay 0-100cm +
Breighton Meadows	Forb-rich MG4 with transitions to MG8 and OV28 present.	Under managed, totally over grown when visited at end of June.	Unknown	Site appeared very wet inplaces with no obvious sources of water. River level was well below that of the field, and the back drainage ditch did not appear to be contected to the river.	
Burley Dene	Vegetation represents drier end of mesotrophic grasslands. Good examples of MG4, MG5a, b, c.	all fields except one appear to be traditionally managed for late hay cutting	None Available	Right at the top end of catchment.	Clay until 90-100cm then sand aggregates appearing within clay. In one field clay appeared gleyed throughout the profile.
Burnfield Meadow, Leckford	Survey was not carried out. Previously an active water meadow and Hampshire CC heritage site.	Appeared to be totally neglected.	Unknown		
Cassington Meadows	Sharp boundary between grassland flood meadow area and rough area dominated	*Heracleum sphodylium* present in quite large	Obtained	Areas subject to gravel extraction less so then	Gravel layer appeared to be at 100cm.

					MG4 M22d	Kelmscot	River terrace drift	Calcareous fine loamy soils over gravel, variably affected by groundwater, associated with non-calcareous clayey soils over gravel.
Castor Flood Meadows	Cambridgeshire	TL123973	42 ha	SSSI	Meadows within the flood plain of the River Nene. Variety of grassland types. MG4 (MG5 MG8 MG13)	Fladbury 1 Sutton 2	River alluvium River terrace gravel	Clayey soils, in places calcareous, variably affected by ground water. Well drained fine and coarse loamy soils usually over gravel with a calcareous matrix.
Clattinger Farm	Wiltshire	SU012933	60 ha	SSSI/SAC	Series of meadows cut for hay and after math grazed. Different floristic content of the meadows. MG4 MG5 (MG9 MG11)	Kelmscot Badsey 2 (Flagham Brook area)	River terrace drift	Calcareous fine loamy soils over gravel, variably affected by groundwater, associated with non-calcareous clayey soils over gravel. Well drained calcareous fine loamy soils over limestone gravel.
Derwent Ings Complex Derwent Ings Ellerton and Wheldrake Ings	North Yorkshire / Humberside	SE703466-703347	662 ha	SSSI/NNR/ SACetc.	Alluvial flood meadow of the Lower Derwent Valley MG4 MG8 MG13 M27	Fladbury 3	River alluvium	Clayey, fine silty and fine loamy soils affected by groundwater.
Ducklington Mead	Oxfordshire	SP363077	5.6 ha	SSSI	Meadow between two arms of the River Windrush managed by hay cutting and aftermath grazing. Variation in wetness across the site. MG4.	Thames	River alluvium	Mainly calcareous clayey soil affected by groundwater.
Dunsdon Farm	Devon	SS307083	39.2 ha	SSSI/NNR	Three meadows situated on the Culm Measures. M24c M27c	Hallsworth 2	Drift from carboniferous sandstone and shale	Slowly permeable seasonally waterlogged clayey, fine loamy and fine silty soils.

	by *Glyceria fluitans* and *Caltha palustris* which was extremely wet and time of survey. Topographic variation between the two areas although soil differences could have been responsible for the community differences.	quanties - suggesting management is not quite right.		Pixey and Yarnton Meads.	Chalky sand also found.
Castor Flood Meadows	Rank MG4 maybe MG1, with *Crepis biennis* prevalent.	Appears to be neglected.	Unknown	to complete	to complete
Clattinger Farm	Extensive area, nine of eleven fields are of high botanical interest. At dry end of flood meadow vegetation.MG5a, MG5b, MG4, MG4/5 and MG5/8 communities present	Some variation in managed, some fileds were cut others grazed by sheep.	Obtained	Similar situation to Cricklade? through flow from one river to another - area subject to gravel extraction	Soil profile differed slighty depending on field unit. Coarse sand or gravel appeared at 70-100cm.
Derwent Ings Complex Derwent Ings Ellerton and Wheldrake Ings	 Ellerton other experimental work. Wheldrake good site for birds! over wet!				
Ducklington Mead	MG4 - with area of more improved or disturbed vegetation in the centre of the field. Slight variation in topography with troughs apparent. East and west sides of field wet boundaries, north and south both dry.	Quite lush growth of grass- seems a little improved although *Fritillaria meleagris* present.	Interim Statement	Similar situation to Cricklade. through flow of water between two arms of river, although ditches adjacent to field would have some effect.	Gravelly sand between 55-100cm depth.
Dunsdon Farm	Site not visited.		Unknown		

East Harnham	Wiltshire	SU151289	17 ha	SSSI	Formerly managed as a water meadow. Variation in wetness across the site MG8 M22 (MG5 MG27)	Frome	Chalky and gravelly river alluvium	Shallow calcareous and non-calcareous loamy soils over flint gravel affected by groundwater.
Lugg Meadows	Herefordshire	SO530410	15 ha	SSSI	Flood Meadow			
Mottey Meadows	Staffordshire	SJ840134	44.6 ha	SSSI/NNR/ SAC	Alluvial flood meadows occupy the greater part of the site. MG4 MG8 (MG5 MG10) Fen Meadow vegetation on peaty soil is also present.	Wigton Moor	River terrace and glaciofluvial drift	Permeable fine and coarse loamy soils, variably affected by groundwater, drier soil - slighty raised sites.
Newton Mask	Humberside	SE707500	16.5 ha	SSSI	MG4 MG5c MG8 MG13 M27	Fladbury 3 Blackwood	River alluvium Glaciofluvial drift	Clayey, fine silty and fine loamy soils affected by groundwater. Deep permeable sandy and coarse loamy soils. Groundwater controlled by ditches.
Old Meadow, Wonston	Hampshire	SU473397	2 ha	non-statutory	Grazed ex-water meadow			
Pixey and Yarnton Meads	Oxfordshire	SP480105	85.6 ha	SSSI/SAC UTT ESA	Flood plain meadows adjacent to the River Thames. Cut annually for hay and the aftermath grazed. MG4 MG5 M22	Thames	River alluvium	Mainly calcareous clayey soil affected by groundwater.

East Harnham	Three units i) ridge and furrow with MG8, ii) MG8 MG8/M22 and MG5a iii) M27 converting to MG8, MG8 and MG8/M22	Some MG8 MG8/M22 and MG5aof the fields seemed heavily poached - no hay cuttting in recent times	Unknown	Complex series of drains.	
Lugg Meadows	MG6b MG5a/6b MG4/5a with *Alopecurus pratensis* MG7 sub-community. Very little *Sanguisorba officinalis* and a relict community of Fritillaria meleagris present. General floristics suggested MG4 may have bee more extensive in the past.	Traditionally managed as a flood meadow some areas cut earlier than others.	Unknown	Site appears too summer dry. Drier than in previous years.	
Mottey Meadows	Six meadows were examined at the site. Compartments 10 and 11 good quality highly typical MG4 grading into two forms of MG4/8 transition. This vegetation type continues in compartment 9B where MG8 proper also exists. Sizeable patches of *Cirsium dissectum* .	Well managed site. Cut, after-math grazed. English Nature owned site.	None available	Site is bounded by a river at one edge, with a ditch bound system along many field edges. Eastern edge of site rising to higher land. Water flow or seepage may occur in this area.	Sand layer starts at 60-80cm. Silt/silty clay or clay depending on compartment
Newton Mask	MG4/8 on slope. Gradual change from sedge community to MG5/7 from south to north in field.	Appeared well managed	Unknown	Obvious seepage flushes on slope to ditch. From ditch to river, large field with little topographic variation.	
Old Meadow, Wonston	MG8 present with a range of of vegetation structure from low swards to tall areas with affinity to M22b. In areas of standing waterthe community tends to S19c. M27b, M23b, MG6b and MG1 also present.	Floristically rich with Geum rivale and Valeriana dioica. Area is small and management recently lapsed.	Unknown		
Pixey and Yarnton Meads	Very little topographic variation with quiye a uniform sward. *Primula veris* very frequent at Yarnton with a clearly defined distribition, however it was found growing with *Carex acutiformis* .	Caltha area in wetter part of Pixey mead probably the result of run off from the A34. Carex species overall more frequent at Pixey Mead.	Obtained	Bounded by the River Thames and ditches - distinct hydrological unit. The road running through Pixey mead could cause problems as could gravel extraction which has been very prevalent in the area over the past ten years.	ARC have hydrogical information.

Portholme	Cambridgeshire	TL238708	104 ha	SSSI/SAC	Surrounded by the River Great Ouse the site is managed as a lammas land MG4	Fladbury 1	River alluvium	Clayey soils, in places calcareous, variably affected by ground water.
Pry and Bottom Meadows	North Yorkshire	SD833917	3.5 ha	SSSI Pennine ESA	Two meadows adjacent to the River Ure. Variation in wetness across the sites with gradation into damp meadow and fen meadow communities. MG3b (M26b MG8 MG9)	Dunkeswick	Till from palaeozoic and mesozoic sandstone and shale	Waterlogged fine loamy and fine loamy over clayey soils, associated with similar clayey soils.
Rectory Farm	Worcestershire	SO922382	16 ha	SSSI	Two meadows adjacent to the River Avon, flood meadow MG4 present as well as MG8			
River Itchen Meadows	Warwickshire	SP403561	45.3 ha	Non-Statutory	Between two tributaries of the River Itchen. MG4	Denchworth	Jurrassic and cretaceous clay	Slowly permeable seasonally waterlogged clayey soils with similar fine loamy over clayey soils.
Severn Ham	Gloucestershire			SSSI	Bounded by the Rivers Severn and Avon at Tewkesbury. Flood meadow vegetation ancient common land for hay cutting and grazing.			
Shapwick Heath	Somerset	ST430403	335 ha	SSSI/NNR	Former raised bog near the River Bure with a variety of grassland communities including MG5 M24	Turbary Moor	Raised bog peat	Deep earthy peaty soils. Groundwater usually controlled by ditches and pumps.

Portholme	Variation in community composition with topography. Areas with *Senecio aquatilis* prevelent as well as typical MG4, however *Sanguisorba officinalis* was not very abundant in areas.	One or two compartments (hay is auctioned in lots) has large amounts of *Anthriscus sylvestris* , suggesting the area had been disturbed in the past.	Unknown		
Pry and Bottom Meadows	MG3 and MG8 communities present divided by distinct boundary in Bottom meadow. *Trollius europeaus* present in Pry meadow (M26) on45^{o} slope.	Appears well managed, sheep were still grazing at the beginning of May. Shut up for hay, grazed later.	Unknown	Water supplied to MG3 by river over topping and rainfall. MG8 as above and run-off from catchment above - water probably flows down the channel in which MG8 lies.	MG3 - lies on shallow loamy soil 40cm over bedrock of limestone. MG8 area lies in a dip and has deeper soil 80cm and is more humic although still a loam.
Rectory Farm	The two units are sharply partioned from east to west with species-poor communities next to the river and more species-rich on the eastern edge. MG6 and MG7 mnear the river MG4 and MG8 elsewhere.	The divisions in the community types is probably a reflection on the past management rather than hydrological differences.	Obtained	Embankment next to the river, with drainage ditches to the north and incomplete along the eastern edge. Seepage may occur from springs in the SE corner.	
River Itchen Meadows	Site not visited. Considered too dry vegetationally and under managed.				
Severn Ham	Areas of MG6 - dominated by *Cynosurus cristatu* . Large area of MG7D *Lolium perenne-Alopecurus pratensis* grassland, superficially dominated by *Holcus lanatus* and *Rananculus acris* . Other areas highly disturbed dominated by *Rumex* spp. and *Urtica dioica* .	Site appears highly disturbed in many areas, with pipe work running accross the site. Used for recreation and dog walking. Designated for the 'Dodder'.	Interim Statement available		
Shapwick Heath	Site not visited				

Sherborne Meadows	Warwickshire	SP242618	21.5 ha	SSSI	Series of eight meadows either side of the Sherbourne Brook. Variation in vegetation with distance from the river. MG4 MG5b.	Brockhurst 2	Permo-triassic reddish mudstone and till.	Slowly permeable seasonally waterlogged reddish loamy over clayey soils. Reddish clayey alluvial soils affected by groundwater.
The Sturts	Herefordshire			SSSI	Wildlife Trust site.			
Upham and Summer Leasow Meadows								
Upton Ham	Hereford and Worcester	SO860400	56.6 ha	SSSI	Adjacent to the River Severn , cut annually for hay with aftermath grazing. MG4 (MG5 MG11)	Hollington	Reddish river alluvium	Deep reddish fine silty and clayey soils variably affected by groundwater.
Wadenhoe and Achurch Meadow	Northamptonshire	TL008828	47.4 ha	SSSI	Meadow adjacent to the River Nene with shallow ditches and drains. MG4 MG5 MG8 MG9 MG13 M27.	Fladbury 1	River alluvium	Clayey soils, in places calcareous, variably affected by ground water.
Wet Moor	Somerset			SSSI Levels and Moors ESA	Raised Water level area of the ESA - recorded in ESA monitoring programme - nested stands NVC communities MG7b/c/d, MG9a, MG10 and MG13.			

Sherborne Meadows	Site not visited. Considered too dry vegetationally and not a discrete hydrological unit on paper.				
The Sturts	Site rather tumbledown, rush mire community prevalent M23a, MG5a found in drier areas which grades into MG9b. Small area of M27 and OV30.	Cattle grazed with evidence of poaching, no areas appear to be shut up for hay. Gives the impression of an unstable pattern of vegetation.	Unknown		
Upham and Summer Leasow Meadows			Interim Statement available		
Upton Ham	Many transitions between damp neutral grassland. Dominated by MG4, MG5b,MG6b, MG7D, MG9a, MG13 are also present with transitions from MG4 to MG6b, MG7D and MG9a	Traditionally managed Lammas hay meadow. Some differences in vegetation maybe due to different cutting regime for different lots.	Interim Statement obtained	River Severn along one edge - level well below field. Drainage ditches which were wet in April visit - dry during the summer. Water balance model controlled by rainfall. Depends on whether gravel exists.	Silty clay 0-60 cm, Silty loam 60-140 cm. increasing clay content with depth. Drainage channel in middle of the field clay more prevalent. No gravel found upto depth of 140 cm.
Wadenhoe and Achurch Meadow					
Wet Moor	Different fields surveyed by M&H 1997 - Calthion. Look see July 98. Fields 7455, 6060, 7476 and 7082 in western block - *Carex disticha* , *Senecio aquaticus* , *Caltha palustris* , *Oenathe fistulosa* all present. Range of communities MG8, MG13.	7455 - grazed on 1/7/98, other fields were ungrazed.	Unknown		Silty peat / humic silt top layer Clay moor

ESA Monitoring	Somerset,Wiltshire and Hampshire, Norfolk, Yorkshire, Lancashire and Durham, Radnor, Oxforshire.				Somerset M22b MG8 Avon Valley MG8 MG9 Test Valley MG5b/CG2c M22b MG8 MG9 MG10 Broads M22 MG6 Pennines MG3a MG3 MG8 Radnor MG3 MG8 M23 Upper Thames Tributaries MG4 MG5

Hydrologically altered sites for consideration (BD1310)

Site Name	Location	NGR	Size	Status	Site and community description	Soil Association	Geology	Soil
Cricklade North Meadow	Wiltshire	SU094946	44.4 ha	SSSI/SAC/ NNR	Flood meadow adjacent to River Thames. Continued site. MG4 MG5 MG13	Kelmscot	River terrace drift	Calcareous fine loamy soils over gravel, variably affected by groundwater, associated with non-calcareous clayey soils over gravel.
Derwent Ings, East Cottingwith	North Yorkshire / Humberside	SE7040	741.9 ha	SSSI/NNR/ SACetc.	MG4 MG5c MG8 MG10a MG10b MG13 M22 M27	Fladbury 3	River alluvium	Clayey, fine silty and fine loamy soils affected by groundwater.
Long Herdon Meadow	Buckinghamshire	SP648202	4.5 ha	SSSI	Meadow adjacent to the River Ray, some ridge and furrow topography. Owned by BBONT. MG4 MG 8 MG9/MG13	Fladbury 1	River alluvium	Clayey soils, in places calcareous, variably affected by groundwater.
Lower Woodford	Wiltshire	SU124347	24 ha	SSSI	Meadows adjacent to the River Avon. Part of the site is an active water meadow. MG8 M22 M27	Frome	Chalky and gravelly river alluvium	Shallow calcareous and non-calcareous loamy soils over flint gravel affected by groundwater.
Stanford End	Berkshire/ Hampshire	SU705633	13.4 ha	SSSI	Series of meadows adjacent to the River Loddon. MG4 MG8 MG13	Wickham 4	Drift over tertiary clay	Slowly permeable seasonally waterlogged fine loamy over clayey and fine silty over clayey soils associated with similar clayey soils, often with brown subsoils.
Tadham	Somerset				Ditch bounded meadows. Continued site. MG5 MG8	Turbary Moor Altcar 1	Raised bog peat Fen peat	Deep earthy peaty soils. Groundwater usually controlled by ditches and pumps. Deep peat soils with earthy topsoil. Groundwater usually controlled by ditches and pumps.

ESA Monitoring	Somerset Levels and Moors				Raised Water Level Area. Four monitored sites changed Tier after review of ESA in 1992. Monitoring data 1988 1990 1995.
	Avon Valley				Tier 2 Option 1 nine sites recorded using nested quadrats in 1993

Bransbury Common Meadows	Hampshire	SU4142			Near River Test. Water meadow/sedge rich meadow MG8	Adventurers' 3	Fen peat, tufa and river alluvium	Deep peat soils and associated extremely calcareous mineral soils. Deep silty and clayey soils with a humose surface horizon in places.
Eakring and Maplebeck Meadow	Nottinghamshire	SK705622	16 ha	SSSI	Site owned Nottinghamshire Trust. MG4 MG8 MG9	Compton	Reddish river alluvium	Reddish clayey soils affected by groundwater.
Muston Meadows	Leicestershire	SK824367	56.6 ha	SSSI/NNR	Ridge and Furrow grassland. MG4 (MG5 MG9a)	Denchworth	Jurrassic and cretaceous clay	Slowly permeable seasonally waterlogged clayey soils with similar fine loamy over clayey soils.

Appendix B

MODELLING THE SOIL-WATER REGIME

The development of different plant communities at a given site depends on the soil-water regime over many years. Since records of soil hydrological data generally do not exist, our approach has been to obtain by modelling an estimate of the soil-water regime on the chosen sites over many years from meteorological records and available hydrological records of bounding watercourses. The models were validated using intensive measurements on the sites over two or three years, having measured the soil hydraulic properties. The observed plant communities were then related to the modelled historical hydrological regime.

The aim was to develop models based on the physics of the situation. The depth of the water table below the soil surface, giving the extent of the unsaturated soil, was the prime consideration in the development of our models and their validation. A common assumption in all our work is that plants respond only slowly to changes in the soil-water regime so that average conditions over time intervals of one week or more provide a reasonable estimate for our purposes. Time constants for water-table movements on the sites were generally much smaller than one week, so that we can consider the non-steady state soil-water profiles occurring as a succession of steady state profiles and use theories derived for steady state soil-water and groundwater movements.

In many cases we were able to develop models using known soil physics and groundwater solutions to particular boundary-value problems. In some cases, however, it was not possible to obtain precise boundary values of the particular site without much further detailed hydrological study of the surrounding area. In these cases, we used less physically-based models but that also required meteorological and soil hydrological inputs. When soil conditions and hydrological boundaries are well defined, the models are based on analytical solutions to hydrological equations. When these factors are not so well defined, the models become more reliant on empirical calibration using field observations.

The modelling of all sites was based on four models that were developed for particular sites that were part of our programme of investigations. These are listed in Table 1 in which is listed site and soil descriptions, together with the soil physical measurements and input data needed for the modelling. A complete list of the sites and models used is given in Table 2. A description of each model follows.

Table1. Basic model types used.

Site	Site Description	Soil Physical Measurements	Input Data
Model I (the "Tadham" model)	Field dimensions Ditch depth Surface topography	Saturated hydraulic conductivity Specific yield Unsaturated hydraulic conductivity exponent	Meteorological records Ditch-water levels
Model II (the "Cricklade" model)	Field dimensions River depths Surface topography	Saturated hydraulic conductivity Specific yield Unsaturated hydraulic conductivity exponent Transmissivity of gravel aquifer	Meteorological records River levels
Model III (the "Upwood" model)	Field dimensions Surface topography	Saturated hydraulic conductivity Specific yield	Meteorological records
Model IV (the "Bourton" model)	Surface topography Surrounding hydrogeology	Saturated hydraulic conductivity Data from dip-wells	Meteorological records

Table 2. Data collection sites with model type used.

Site	Model
Belaugh	I
Blackthorn	III
Bourton	IV
Broad Dale	III
Cricklade	II
Dancing Gate	IV
East Cottingwith	III
East Harnham	I
Moorlinch	I
Mottey Meadows	I
Portholme	II
Southlake	I
Southlake	I
Stonygillfoot	I
Tadham	I
Upwood	III
West Sedgemoor	I
Wet Moor	I

Model I: The ditch-bounded water-table model (the "Tadham" model).

The ditch-bounded water-table model (Youngs et al., 1989; Gowing et al., 1998) was developed for flat low-lying lands with high permeability soils, intersected by a network of water-filled ditches. At the sites investigated, fields were approximately rectangular in shape (although this is not a necessary condition for the use of the model) with ditches along each edge. During the winter the ditches generally drain the field and the water table is dome shaped, falling from a peak in the field centre to the level of the top of the seepage surface at the ditch, as illustrated in Fig.1a. Drainage theory has been developed to relate water-table heights to rainfall rate for this three-dimensional drainage situation (Childs & Youngs, 1961; Youngs, 1992, 1999) and this forms the basis of the model used to characterise the soil-water regime.

Steady-state land-drainage theory gives the water-table height, expressed as a fraction of the drain spacing $2D$ midway between drains of a parallel drainage system, as a function of the ratio of the steady rainfall q on the surface and the soil's hydraulic conductivity K. In our model we used a power-law relationship (Youngs, 1985). The lower water table caused by the rectangular layout of ditches and the position in question being off-centre is accommodated by using a shape factor A obtained theoretically using the concept of seepage potential (Youngs, 1992). We thus obtain the water-table height H above the ditch base at any position in the field in the form

$$\frac{H}{D} = f\left(A\frac{q}{K}, \frac{H_d}{D} \right) \qquad (1)$$

where H_d is the height of water in the ditches. In the model we used Youngs' (1985, 1991) power law relationship between H/D and q/K and write

$$A\frac{q}{K}=\left(\frac{H}{D}\right)^{\alpha}-\left(\frac{H_d}{D}\right)^{\alpha}$$

where a is a parameter that varies between 1.384 for an infinitely deep soil and 2.0 for a soil overlying an impermeable soil below the base of the ditch.

The water-table height in the field when there is steady-state evaporation can also be calculated using the same equation. Then the water table is lowered below the level of water in the ditches, creating a bowl-shaped water table, as illustrated in Fig.1b. When the water table falls below a critical depth, the soil-water pressure in the root zone begins to fall rapidly and evaporation is reduced. The evaporation rate *E*, calculated directly from meteorological data for high water tables, becomes soil-dependent and is calculated from a steady-state solution of Richards' equation, assuming an exponential relationship between the hydraulic conductivity and the soil-water pressure *p*, that is $K = K_0 \exp(cp)$ (Gardner, 1958). Thus:

$E = E_0$, the potential evaporation rate, when the soil is not limiting evaporation

$E=\dfrac{K_0}{\exp(cw)-1}$, where *w* is the depth of the water table below the soil surface, when the water table is at a depth limiting the evaporation.

In the non-steady state situation when there is a moving water table, with the assumption that the non-steady state water tables can be considered as a succession of steady state ones, *q* in Equation (1) has to be replaced by the momentary flux $-V$ through the water table, which is

$$V = V_s + S\frac{\partial H}{\partial t} \qquad (2)$$

where V_s is the flux through the soil surface (equal to the evaporation rate minus the rainfall rate), *S* is the soil's specific yield and *H* is the water-table height at time *t*. The change in water-table height ΔH during the time interval Δt can then be calculated from the average evaporation and rainfall rates and the average ditch-water levels, knowing the soil's hydraulic properties, by using equation (2) in the chosen drainage equation to obtain

$$\Delta H=\left[\frac{K_1-K_0}{ASD^2}\{k(\overline{H}_d-b)^2-j(\overline{H}-b)^2\}+\frac{K_0}{ASD^{\alpha}}\{\overline{H}_d^{\alpha}-i(i\overline{H})^{\alpha}\}-\frac{V_s}{S}\right]\Delta t \qquad (3)$$

where $\overline{H}_d$ and $\overline{H}$ are the mean values of H_d and *H*, respectively, during the time interval Δt, K_0 is the hydraulic conductivity of the subsoil and K_1 that of the topsoil with the interface between the two occurring at a height *b* above the ditch base, and $j=1$ when $H>b$, $j=0$ when $H<b$, $k=1$ when $H_d>b$, $k=0$ when $H_d<b$, and $i = 1$ when $(H_d/D)^{\alpha} > V_s/K$ and $i = -1$ when $(H_d/D)^{\alpha} < V_s/K$. If surface ponding of water occurs, then $H = 0$ during the given time interval.

The model gives the time dependent water table height at a site for given inputs of effective surface precipitation and ditch-water levels. From measurements of the level of the soil surface relative to the base of the ditch, the depth of the water table below the surface is known. This model was used to calculate the water-table regime in the sites at **Belaugh**, **Moorlinch**, **Southlake**, **Tadham**, **West Sedgemoor** and **Wet Moor**.

A modification to the model was employed for some sites at **Tadham** and for the site at **Stonygillfoot** to take into account different ditch-water levels. Assuming the flow is only in the *x*-direction normal to ditches with water levels H_1 and H_2 distance 2*D* apart, the change in water-table height *ΔH* at coordinate x during the time interval Δ*t* is calculated from

$$\Delta H = \left[\frac{K_0}{SD^\alpha} \left\{ \overline{H}_1^\alpha - i(i\overline{H})^\alpha - [\{\overline{H}_1^\alpha - i(i\overline{H}_2)^\alpha] \frac{x}{2D} \right\} \frac{D^2}{x(2D-x)} - \frac{V_s}{S} \right] \Delta t \tag{4}$$

For these sites the difference in conductivity between the topsoil and subsoil was assumed to be negligible.

The site at **East Harnham** lay between the river and a water-filled ditch with a bund of consolidated clay soil next to the river. In this case the small hydraulic conductivity of the consolidated clay bund next to the river bank was taken into consideration, and the change in water-table height Δ*H* at coordinate x during the time interval Δ*t* was then calculated from

$$\Delta H = \left[\frac{X - K_0 \overline{H}^2/2}{SY} - \frac{V_s}{S} \right] \Delta t \tag{5}$$

where

$$X = \frac{(H_r^2 - H_d^2)(L-x)}{2[L/K_0 - L_c(1/K_c - 1/K_0)]} + \frac{K_0 H_d^2}{2}$$

and

$$Y = \frac{L^2 - x^2}{2} - \frac{[L^2/K_0 + L_c^2(1/K_c - 1/K_0)](L-x)}{2[L/K_0 + L_c(1/K_c - 1/K_0)]}$$

where H_r and H_d are the water levels in the river and ditch respectively, *L* the distance between the river and ditch, L_c the width of the clay bund, K_0 the hydraulic conductivity of the soil and K_c the hydraulic conductivity of the clay bund.

Model II: The shallow aquifer-controlled water-table model (the "Cricklade" model).

This model was developed to model the water-table regime in flood plains where alluvial soils overly very permeable sand and gravel deposits that form a shallow aquifer with hydraulic connection with rivers (Gowing and Youngs,1997; Gowing et al., 1998). This aquifer transmits the hydraulic head from the rivers across the whole site, giving rise to a hydraulic head boundary condition at the base of the alluvial soil deposit above. Soil-water flow in the latter thus takes place on account of this boundary condition imposed from below and the meteorological conditions at the soil surface. The position of the water table in the alluvial soil can then be obtained directly from Darcy's law.

Considering horizontal flow between two rivers distance L apart with water levels H_1 and H_2 above a given datum, as shown in Fig.2, the hydraulic head h at distance x from the first river when there is a steady uniform upward flux V into the alluvial soil above, is given by

$$h = H_1 - (H_1 - H_2)\frac{x}{L} - \frac{V}{2T}(Lx - x^2) \tag{6}$$

where T is the transmissivity of the shallow aquifer. The water-table position in the topsoil is calculated assuming the non-steady state to approximate to a succession of steady states by applying Darcy's law to the flow through the saturated region of the topsoil profile. The flux V is given by Equation 2, so that if w is the depth of the water table below the soil, Darcy's law then gives

$$h = d - w + (s - w)\left(\frac{V_s}{K} - \frac{S}{K}\frac{\partial w}{\partial t}\right) \tag{7}$$

where d is the spot height from which heads are measured at the given position and s is the depth of topsoil.

By using Equation (7) in Equation (6), the rate of change of the water-table depth can be found from the river levels, meteorological data, and hydraulic properties of the topsoil and shallow aquifer. The model thus provides the incremental change in water-table depth during the given time interval, so that the depth to the water table as a function of time can be obtained by numerical calculation.

A more general version of this model takes into account resistance to flow due to soil consolidation near the river banks. The change Δw in the depth of water table at coordinate x during the time interval Δt is then calculated from

$$\Delta w = \left[V_s - \frac{d - \overline{w} - M}{N - (s - \overline{w})/K}\right]\frac{\Delta t}{S} \tag{8}$$

where

$$M = (a_2 - a_1)x/L + a_1$$

with $a_1 = H_1 + \dfrac{(H_2 - H_1)R_1}{R_1 + R_2 - L/T}$ and $a_2 = H_2 + \dfrac{(H_1 - H_2)R_2}{R_1 + R_2 - L/T}$

and

$$N = x^2/2T + (b_2 - b_1)x/L - Lx/2T + b_1$$

with $b_1 = \dfrac{LR_1R_2 - L^2R_1/2T}{R_1 + R_2 - L/T}$ and $b_2 = \dfrac{LR_1R_2 - L^2R_2/2T}{R_1 + R_2 - L/T}$.

In modelling water-table changes at **Cricklade,** $R_1 = R_2 = 0$**.** In modelling **Portholme,** resistances were included.

Model III: The ridge and furrow water-balance model (the "Upwood" model).

This model was developed for the water-table regime for low permeability clay soils used for pasture that have a ridge and furrow drainage system to remove excess water (Gowing et al., 1998). If the field slopes towards one edge where a raised area prevents water draining out from the furrows, the water ponds in the furrows for long periods of time, especially during the winter months. When the water level in the furrows is below the threshold level determined by the height of the overspill, the whole area forms a basin that collects incident rainfall which is lost predominantly through evaporation with a small amount being lost through deep seepage. Because of the slope of the field, water is present in the furrows in the lower part of the field when the furrows higher up the field are dry. The amount of standing water varies according to the amount of water received on to the area and the amount lost. Analysis of the microtopography, combined with a water balance approach, allows the water-table behaviour to be modelled. Computing is facilitated by assuming the ridges and furrows are triangular in shape.

While the subsoil is very impermeable, the topsoil has typically a hydraulic conductivity value of ~0.2 m d^{-1} so that, with the small spacing of about 5 m between ridges, the time constant (see, for example Dougherty et al., 1995) for the lateral drainage to the furrows is less than ~0.1 d. Thus, in the lower part of the field where water stands in the furrows, the water-table height within the ridges does not depart significantly from the height of the standing water in the furrows. However, higher in the field where water is absent from the furrows, drainage downslope occurs over larger distances to the free water in the furrows lower in the field, and this raises the water-table level above that of the standing water. The water-table height H_L at the top end of the field is given by the Dupuit-Forcheimer approximate analysis assuming horizontal flow, leading to

$$H_L = (L - L_S)\sqrt{\frac{V}{K}} + H_0 \tag{9}$$

where H_0 is the level of water in the furrows.. In Equation (9) L is the total length of the furrows and ridges, L_S is the length of furrows with standing free water and K is the hydraulic conductivity of the topsoil. V is the flux of water through the water table defined as

$$V = V_s + S\frac{\partial H}{\partial t} + P \tag{10}$$

where P is the rate of deep seepage and S is the specific yield as before. Hence the water- table change $\Delta H'$ over this area during the time interval Δt is

$$\Delta H' = \left[K\left(\frac{H_L - H_0}{L - L_S}\right)^2 - V_s - P\right]\frac{\Delta t}{S} \tag{11}$$

The area of standing water in the field is assumed to evaporate at a rate calculated as for open water; the area of non-flooded field is assumed to evaporate at the potential evaporation rate for a grass crop. A water balance for the lower area of the field is made, noting that the seepage Q from higher up the field is given from Equation (9) by

$$Q = 2D(L - L_S)V = 2KD(L - L_S)\left(\frac{H_L - H_0}{L - L_S}\right)^2 \qquad (12)$$

where $2D$ is the spacing between furrows. If A is the area of open water on the field, then

$$[-2DL_S(R - P) + AE_0 + (2DL_S - A)E_T + Q]\Delta t = [A + S(A - 2DL_S)]\Delta H \qquad (13)$$

giving the change in height of the standing water ΔH as

$$\Delta H = \frac{[2DL_S(E_T - R - P) + A(E_0 - E_T) + Q]\Delta t}{A + S(A - 2DL_S)} \qquad (14)$$

With data sets of rainfall and evaporation, the change in water table height can be estimated from Equation (11) for the higher part of the field where the furrows contain no water, and from Equation (14) for the lower part of the field where water stands in the furrow. Thence, from the surface topography of the field the water-table depth below the soil surface at any position in the field is obtained. When the water-table depth reaches the impermeable clay subsoil, soil-water deficits are calculated weekly until this is returned to the value when the water-table was lost. The model then resumes.

Water-table regimes at **Upwood** and **Blackthorn** were modelled using this method. A simpler water balance approach was used to model the behaviour at **Broad Dale** and **East Cottingwith**.

Model IV: Foreign water seepage model based on *Modelmaker* (the "Bourton" model).

A physics-based model to trace the water-table regime is sometimes not possible because of the lack of being able to specify the exact physical boundaries of the site although being able to list the physical factors causing the water-table fluctuations. In this case resort has been made to *Modelmaker*. For this model we could provide good meteorological data and an insight into the the hydrogeology of the area and its surrounds. These factors were linked to water-table height measurements at particular locations on the site and a correlation found between them using the tool.

This model was used to provide traces of the water-table behaviour at **Bourton** and **Dancing Gate**.

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Appendix C

Soil parameters used in the hydrological modelling

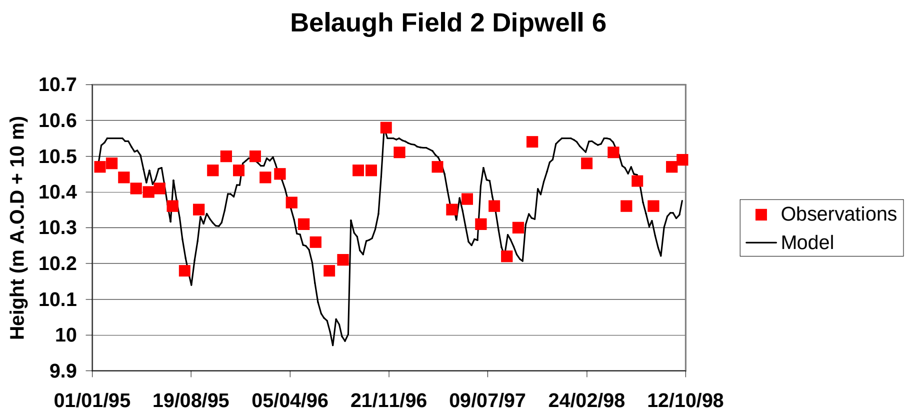
Site Name	Generic model	Topsoil hydraulic conductivity (m day^{-1})	Subsoil hydraulic conductivity (m day^{-1})	Topsoil drainable porosity	Subsoil drainable pororsity	Unsaturated hydraulic conductivity exponent
Belaugh	I	3.0	3.0	0.3	0.3	8
Blackthorn	III	0.22	<0.01	0.06	0.03	3
Broaddale	III	0.7	0.35	0.14	0.09	4
Cricklade	II	0.24	3.5	0.12	0.12	7
Dancing Gate	IV	-	-	-	-	-
East Cottingwith	III	-	-	-	-	-
East Harnham	I	5.7	-	0.11	-	8
Moorlinch	I	0.6	0.6	0.16	0.16	8
Mottey Meadows	II	1	-	0.13	-	8
Nethercote	IV	0.41	0.73	0.1	-	-
Portholme	II	0.2	3.5	0.12	0.1	7
Southlake	I	0.08	1	0.12	0.14	7
Stonygillfoot	I	2.3	2.3	0.1	0.1	11
Tadham	I	2.5	1.75	0.15	0.15	8
Tadham ESA	I	2.5	1.75	0.15	0.15	8
Upton Ham	III	0.9	0.7	0.11	0.11	5
Upwood	III	0.22	<0.01	0.06	0.02	3
Westhay ESA	I	2.5	1.75	0.15	0.15	8
West Sedgemoor	I	1.5	1.5	0.27	0.27	6.4
Wet Moor	I	0.1	3.35	0.06	0.15	8

Site Variables

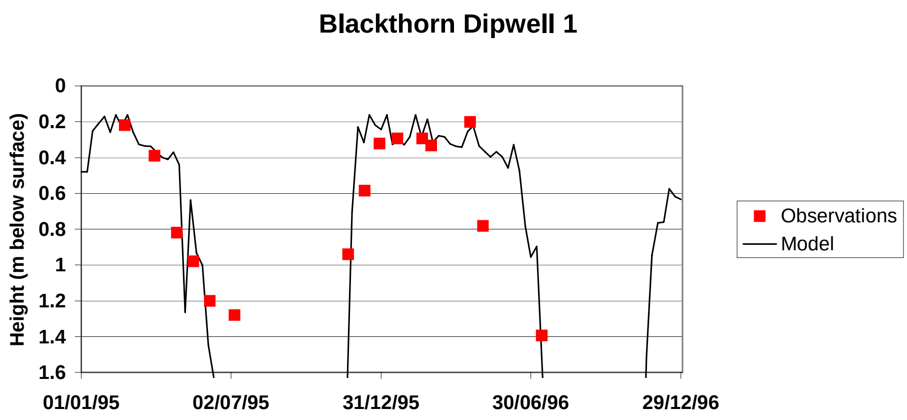
Site Name	Rainfall (mm) *	Potential transpiration (mm) *	SMD (mm) (end July) *	Drought threshold (cm)	Aeration threshold (cm)
Belaugh	575	531	107	49.4	35.7
Blackthorn	669	511	90	48.5	23.5
Broaddale	1663	375	0	47.7	30.4
Cricklade	726	503	82	44.6	34.1
Dancing Gate	1045	444	39	46.4	35.9
East Cottingwith	643	486	85	-	-
East Harnham	799	511	86	49.6	44.3
Moorlinch	865	523	85	46.8	27.3/26.2
Mottey Meadows	700	498	86	46.4	25.6
Nethercote	726	503	82	49.1	28.9
Portholme	574	523	103	48.3	38.7
Southlake	865	523	85	48.7	42.0
Stonygillfoot	1068	404	33	47.4	23.3
Tadham	865	523	85	48.8	35.6
Tadham ESA	865	523	85	48.8	35.6
Upton Ham	775	514	78	48.2	35.6
Upwood	574	523	103	48.5	23.5
Westhay ESA	865	523	85	48.8	35.6
West Sedgemoor	865	523	85	49.3	44.7
Wet Moor	865	523	85	49.3	42.7

* rainfall, PT and SMD taken from Smith L.P. and Trafford B.D. (1976)

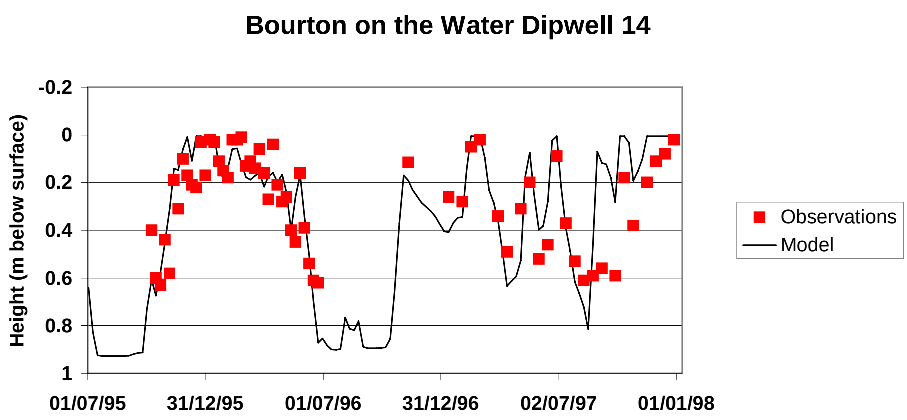
Appendix D



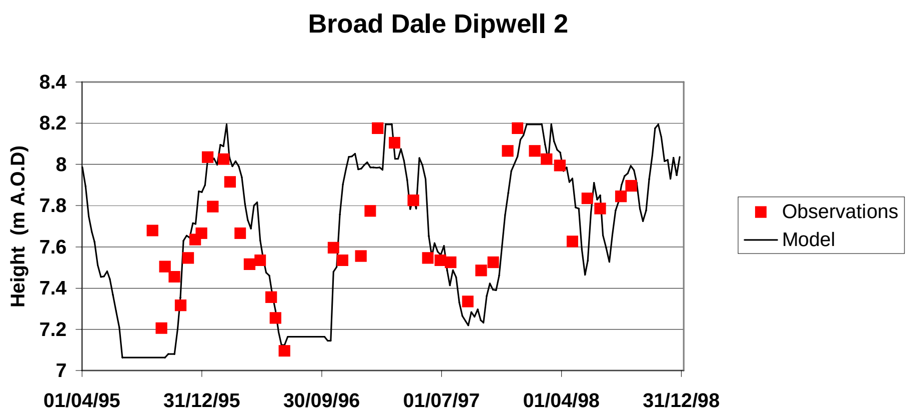
Belaugh Field 2 Dipwell 6
Height (m A.O.D + 10 m)
10.7
10.6
10.5
10.4
10.3
10.2
10.1
10
9.9
01/01/95
19/08/95
05/04/96
21/11/96
09/07/97
24/02/98
12/10/98
Observations
Model



Blackthorn Dipwell 1
Height (m below surface)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
01/01/95
02/07/95
31/12/95
30/06/96
29/12/96
Observations
Model

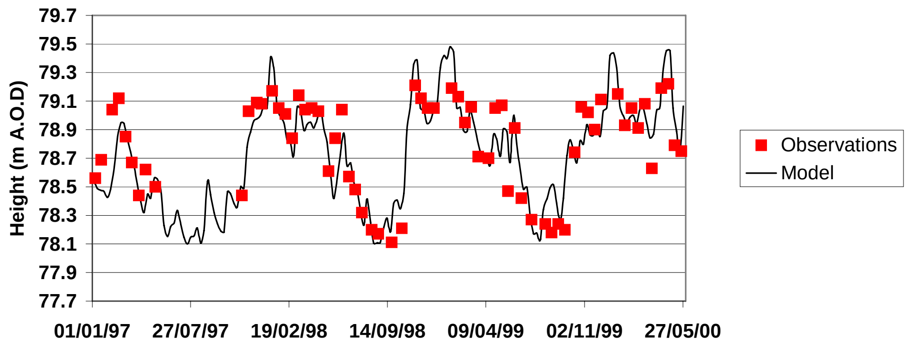


Bourton on the Water Dipwell 14
Height (m below surface)
-0.2
0
0.2
0.4
0.6
0.8
1
01/07/95
31/12/95
01/07/96
31/12/96
02/07/97
01/01/98
Observations
Model

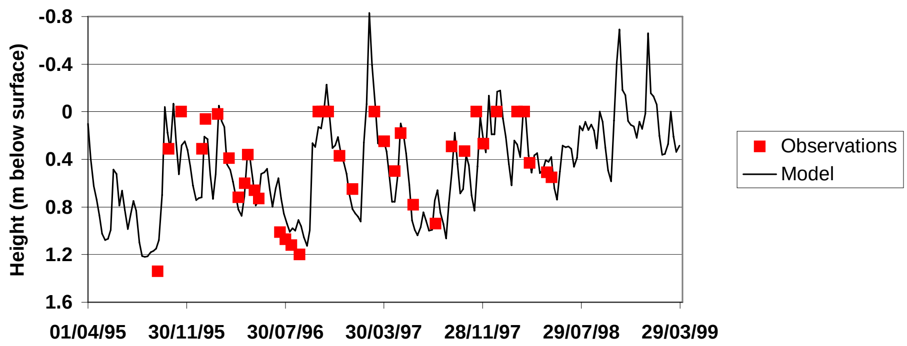


Broad Dale Dipwell 2
Height (m A.O.D)
8.4
8.2
8
7.8
7.6
7.4
7.2
7
01/04/95
31/12/95
30/09/96
01/07/97
01/04/98
31/12/98
Observations
Model

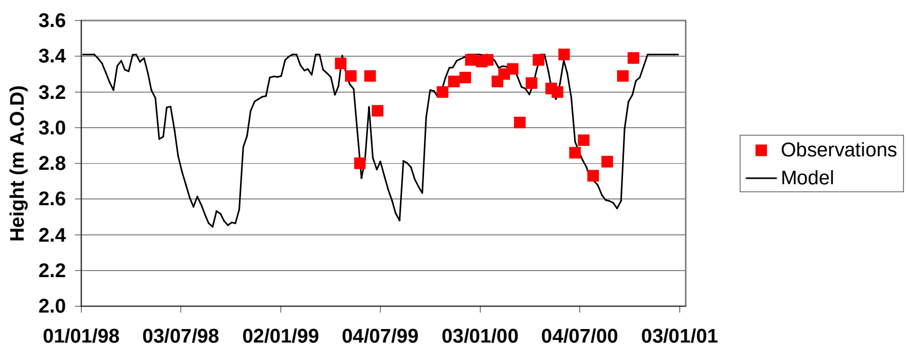
Cricklade Dipwell 4



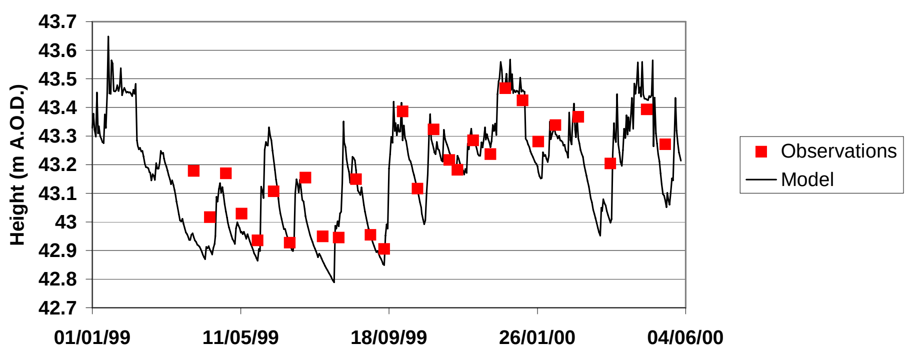
Dancing Gate Dipwell 5

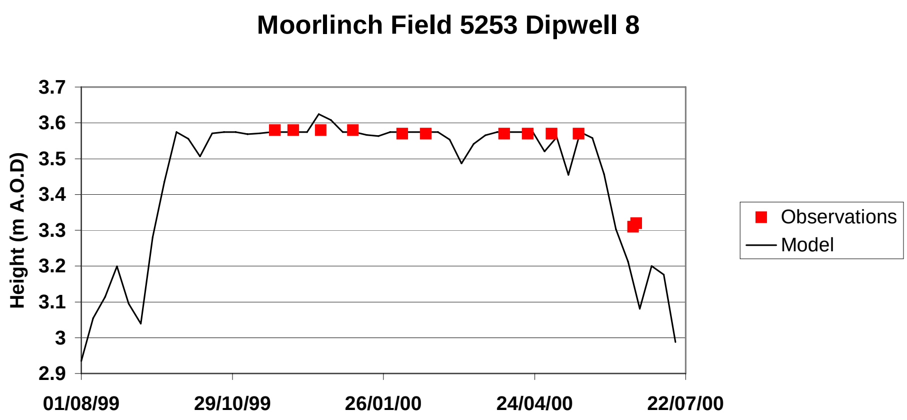


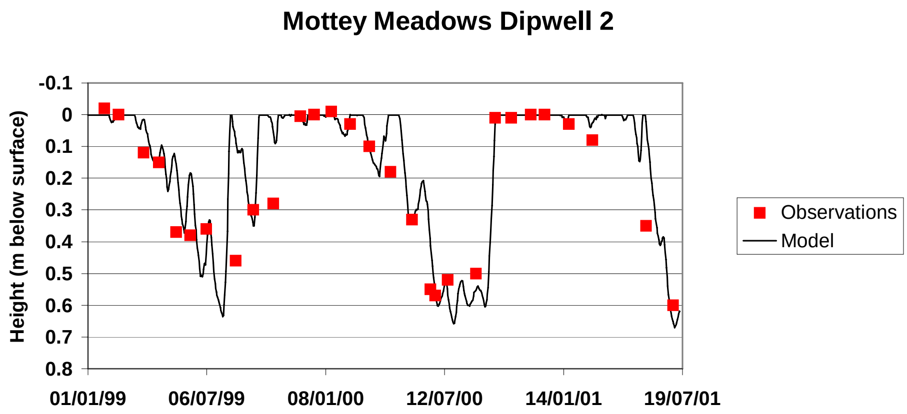
East Cottingwith Dipwell I

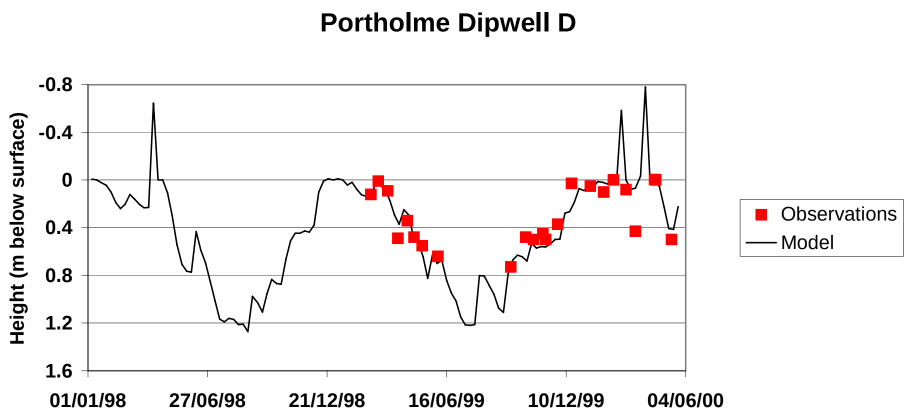


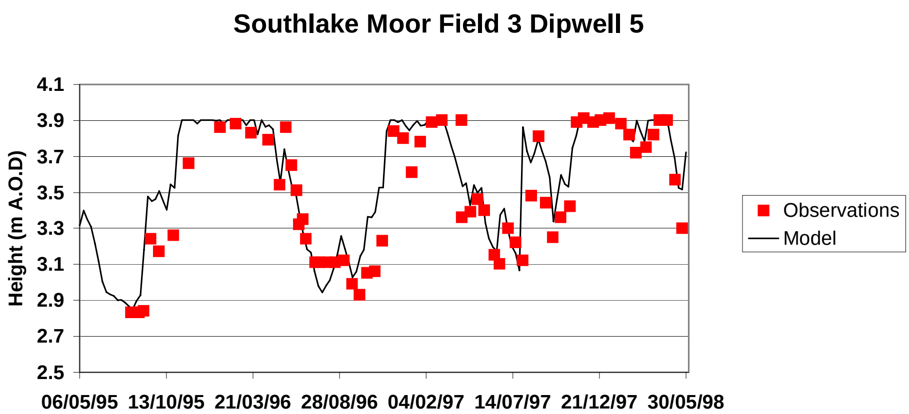
East Harnham Dipwell G

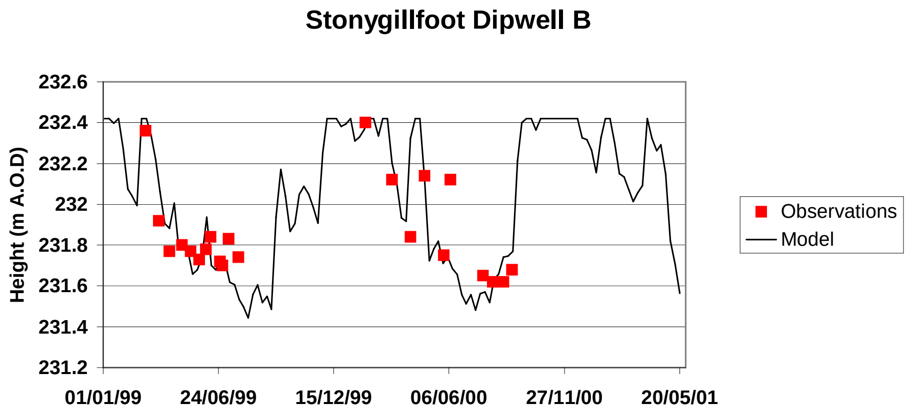


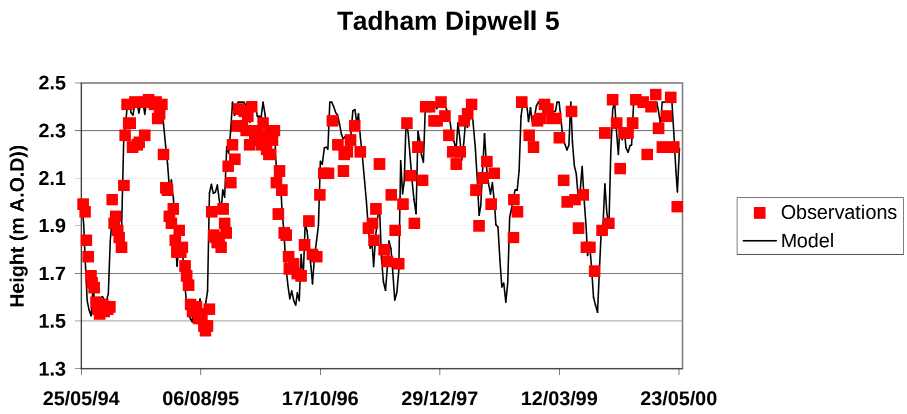

Moorlinch Field 5253 Dipwell 8
Height (m A.O.D)
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3
2.9
01/08/99
29/10/99
26/01/00
24/04/00
22/07/00
Observations
Model

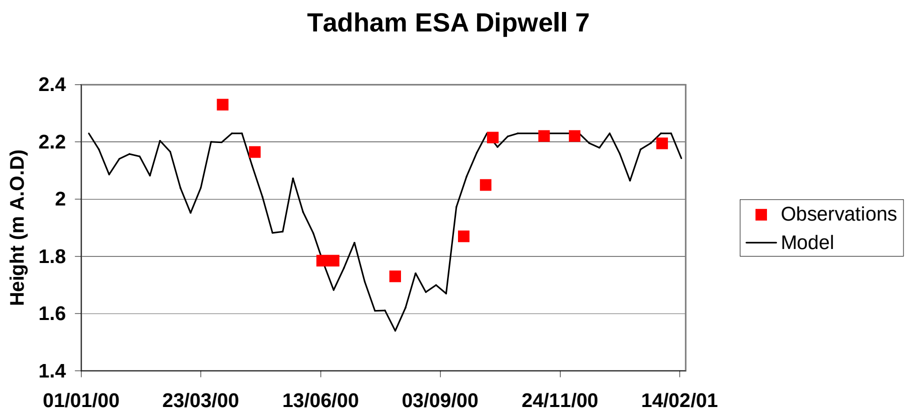

Mottey Meadows Dipwell 2
Height (m below surface)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
01/01/99
06/07/99
08/01/00
12/07/00
14/01/01
19/07/01
Observations
Model

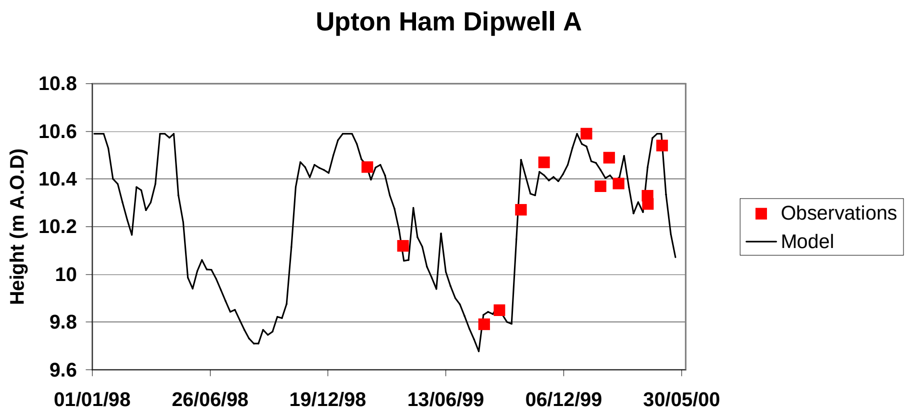

Portholme Dipwell D
Height (m below surface)
-0.8
-0.4
0
0.4
0.8
1.2
1.6
01/01/98
27/06/98
21/12/98
16/06/99
10/12/99
04/06/00
Observations
Model

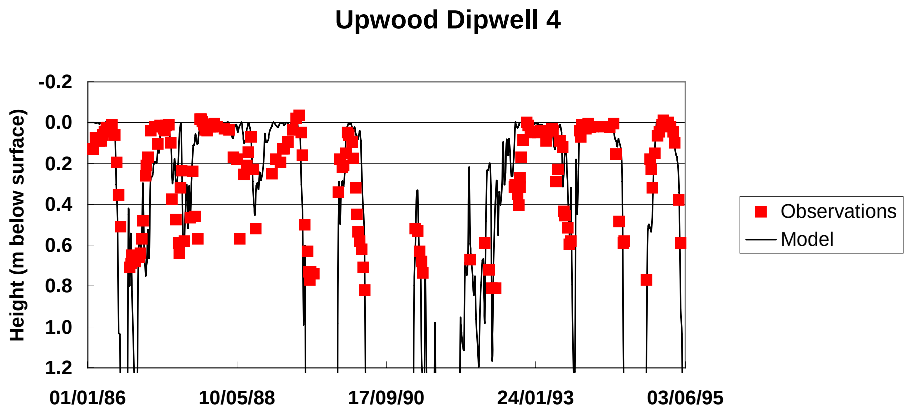

Southlake Moor Field 3 Dipwell 5
Height (m A.O.D)
4.1
3.9
3.7
3.5
3.3
3.1
2.9
2.7
2.5
06/05/95
13/10/95
21/03/96
28/08/96
04/02/97
14/07/97
21/12/97
30/05/98
Observations
Model

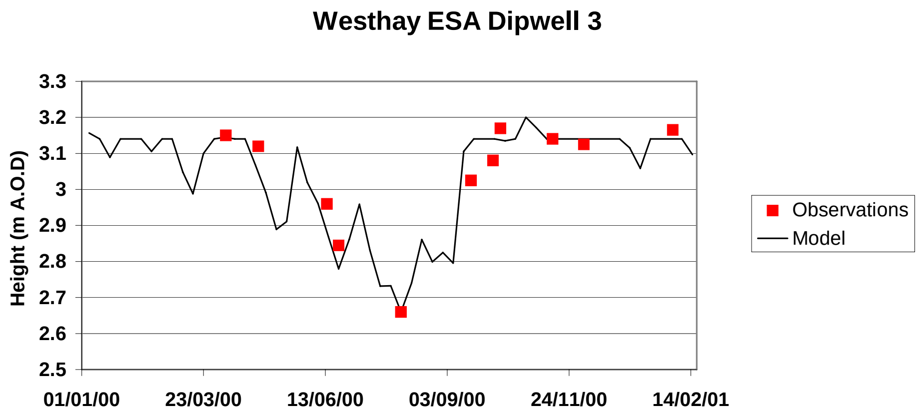

Stonygillfoot Dipwell B
232.6
232.4
232.2
232
231.8
231.6
231.4
231.2
Height (m A.O.D)
01/01/99
24/06/99
15/12/99
06/06/00
27/11/00
20/05/01
Observations
Model

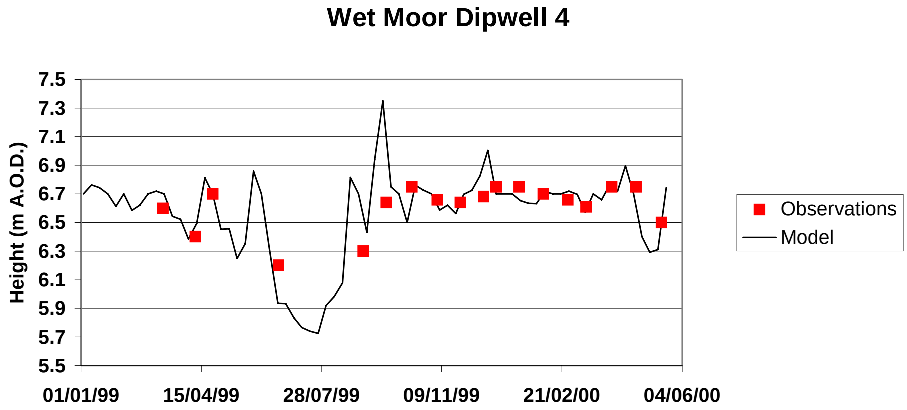

Tadham Dipwell 5
2.5
2.3
2.1
1.9
1.7
1.5
1.3
Height (m A.O.D))
25/05/94
06/08/95
17/10/96
29/12/97
12/03/99
23/05/00
Observations
Model

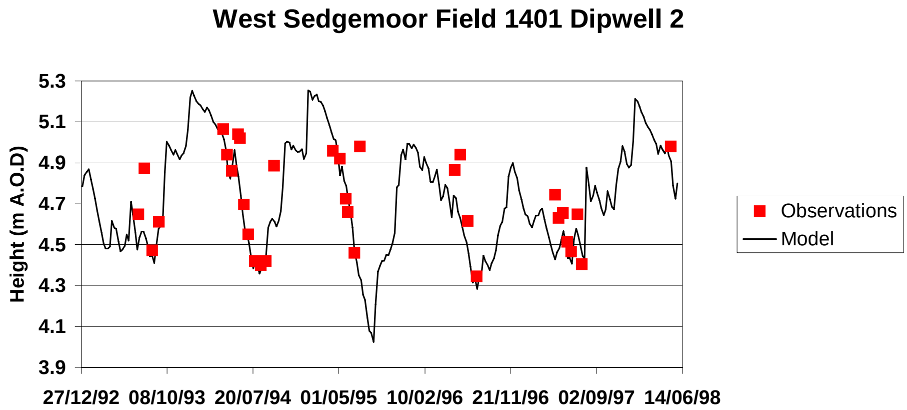

Tadham ESA Dipwell 7
2.4
2.2
2
1.8
1.6
1.4
Height (m A.O.D)
01/01/00
23/03/00
13/06/00
03/09/00
24/11/00
14/02/01
Observations
Model


Upton Ham Dipwell A
10.8
10.6
10.4
10.2
10
9.8
9.6
Height (m A.O.D)
01/01/98
26/06/98
19/12/98
13/06/99
06/12/99
30/05/00
Observations
Model


Upwood Dipwell 4
Height (m below surface)
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
01/01/86
10/05/88
17/09/90
24/01/93
03/06/95
Observations
Model


Westhay ESA Dipwell 3
Height (m A.O.D)
3.3
3.2
3.1
3
2.9
2.8
2.7
2.6
2.5
01/01/00
23/03/00
13/06/00
03/09/00
24/11/00
14/02/01
Observations
Model


Wet Moor Dipwell 4
Height (m A.O.D.)
7.5
7.3
7.1
6.9
6.7
6.5
6.3
6.1
5.9
5.7
5.5
01/01/99
15/04/99
28/07/99
09/11/99
21/02/00
04/06/00
Observations
Model


West Sedgemoor Field 1401 Dipwell 2
Height (m A.O.D)
5.3
5.1
4.9
4.7
4.5
4.3
4.1
3.9
27/12/92
08/10/93
20/07/94
01/05/95
10/02/96
21/11/96
02/09/97
14/06/98
Observations
Model

Appendix E

Favoured water-regime ranges by species

This appendix gives plots for 99 species, each of which occurs >100 times in the project database and was found on at least three separate sites.

All plots are of the same format:

- The vertical axis shows the SEV(waterlogging) in units of metre.weeks and the horizontal axis SEV(soil drying) in the same units.
- The combined shaded and striped area represents the extent of the water regime range for which there is sufficient data for statistical analysis,
- The shaded zone represents the region, within this total area, in which the named species occurs at a significantly (P>0.05) higher frequency than it would do were its distribution independent of water regime.

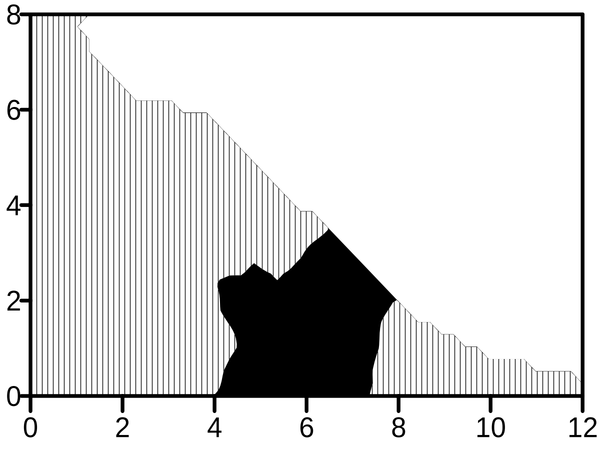
It is the area of dark tone that is said to reflect the "favoured" water regime of the species.

Some species are distributed evenly across regimes and therefore show little or no "favoured" area, e.g. *Plantago lanceolata*.

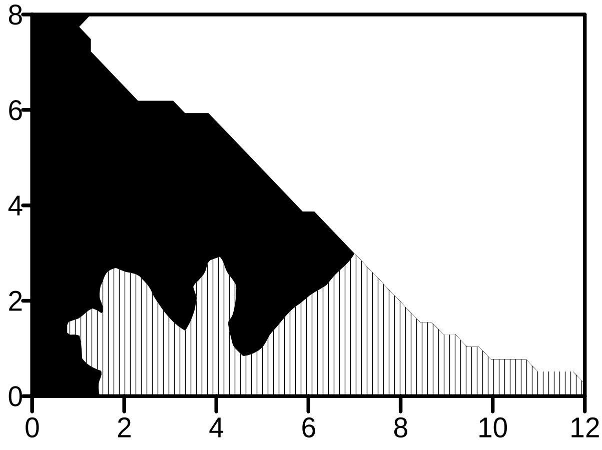
This appendix holds plots of the following species arranged in alphabetical order:

Achillea millefolium	*Lathyrus pratensis*
Agrostis capillaris	*Leontodon autumnalis*
Agrostis stolonifera	*Leontodon hispidus*
Alopecurus geniculatus	*Leontodon saxatilis*
Alopecurus pratensis	*Leucanthemum vulgare*
Anthoxanthum odoratum	*Lolium perenne*
Arrhenatherum elatius	*Lotus corniculatus*
Bellis perennis	*Lotus pedunculatus*
Brachythecium rutabulum	*Luzula campestris*
Briza media	*Lychnis flos-cuculi*
Bromus commutatus	*Lysimachia nummularia*
Bromus hordeaceus	*Myosotis discolor*
Bromus racemosus	*Myosotis laxa*
Calliergon cuspidatum	*Oenanthe fistulosa*
Caltha palustris	*Ophioglossum vulgatum*
Cardamine pratensis	*Persicaria amphibia*
Carex acuta	*Phalaris arundinacea*
Carex acutiformis	*Phleum pratense*
Carex disticha	*Plantago lanceolata*
Carex flacca	*Poa humilis*
Carex hirta	*Poa pratensis*
Carex nigra	*Poa trivialis*
Carex panicea	*Potentilla anserina*
Carex riparia	*Potentilla reptans*
Centaurea nigra	*Primula veris*

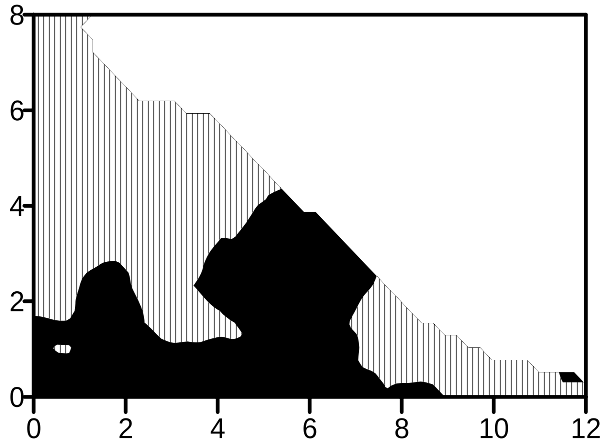
Cerastium fontanum	*Prunella vulgaris*
Cirsium arvense	*Ranunculus acris*
Cirsium palustre	*Ranunculus bulbosus*
Cynosurus cristatus	*Ranunculus flammula*
Dactylis glomerata	*Ranunculus repens*
Deschampsia cespitosa	*Rhinanthus minor*
Eleocharis palustris	*Rhynchostegium confertum*
Elytrigia repens	*Rumex acetosa*
Equisetum palustre	*Rumex crispus*
Eurhynchium praelongum	*Sanguisorba officinalis*
Festuca arundinacea	*Senecio aquaticus*
Festuca pratensis	*Silaum silaus*
Festuca rubra	*Stellaria graminea*
Filipendula ulmaria	*Succisa pratensis*
Galium palustre	*Taraxacum agg.*
Galium verum	*Thalictrum flavum*
Glyceria fluitans	*Tragopogon pratensis*
Glyceria maxima	*Trifolium dubium*
Heracleum sphondylium	*Trifolium pratense*
Holcus lanatus	*Trifolium repens*
Hordeum secalinum	*Trisetum flavescens*
Hypochoeris radicata	*Veronica serpyllifolia*
Juncus acutiflorus	*Vicia cracca*
Juncus articulatus	
Juncus effusus	
Juncus inflexus	



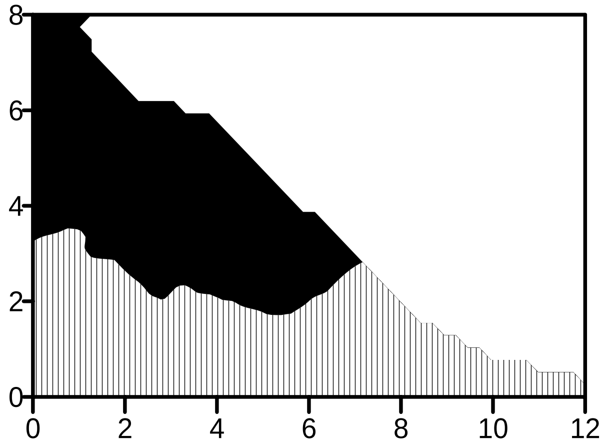
Achillea millefolium



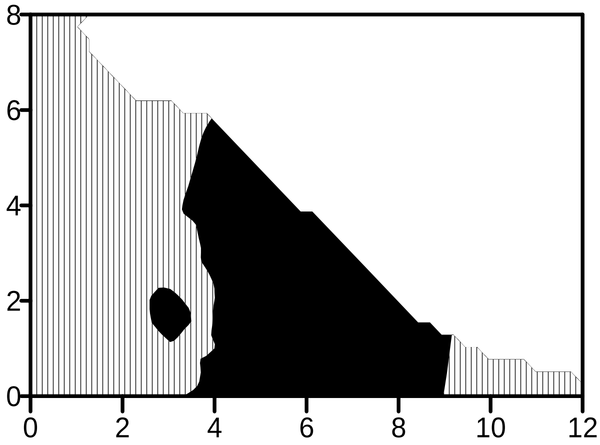
Agrostis stolonifera



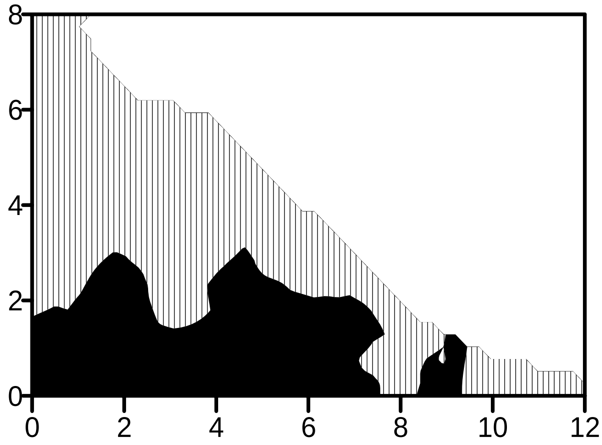
Agrostis capillaris



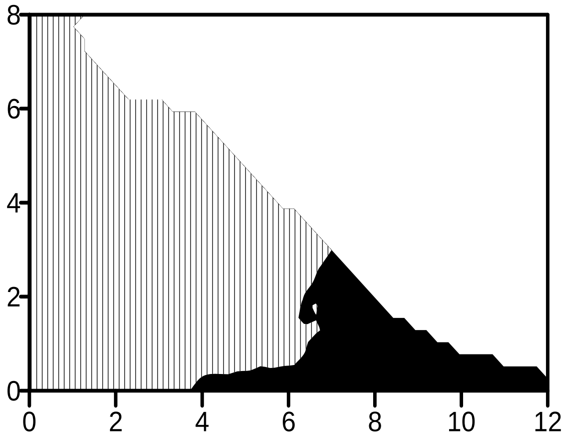
Alopecurus geniculatus



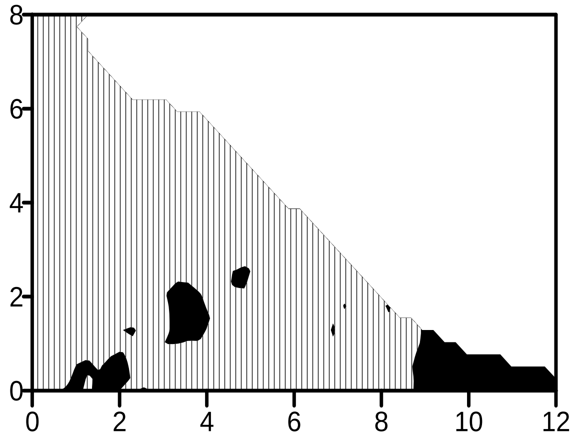
Alopecurus pratensis



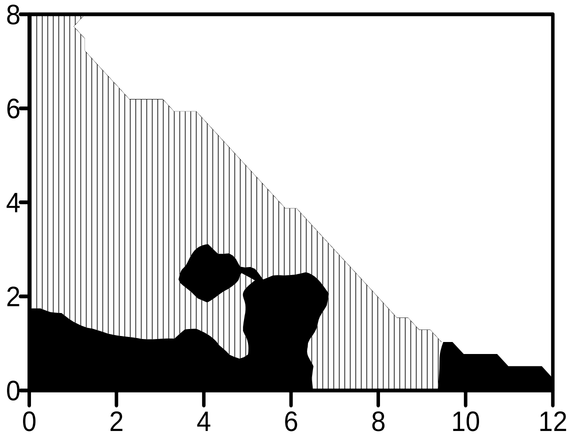
Anthoxanthum odoratum



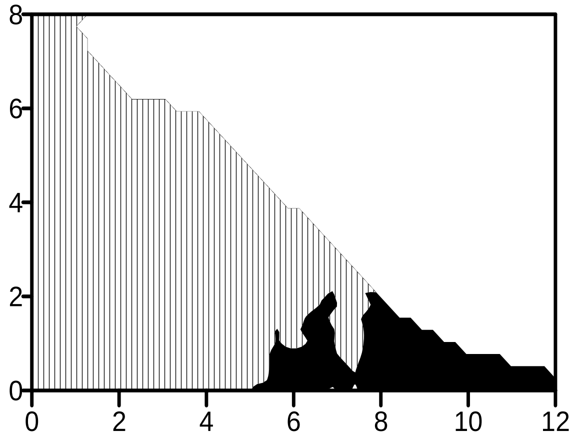
Arrhenatherum elatius



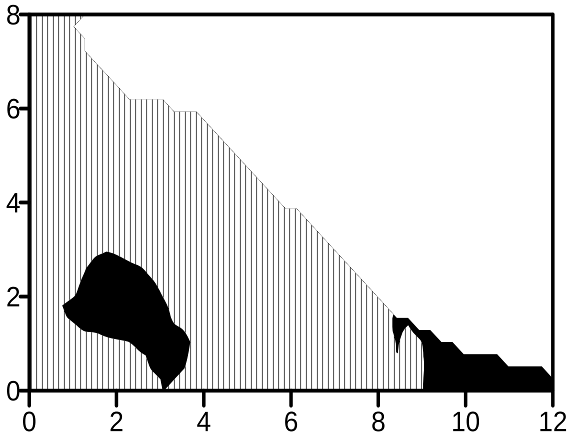
Bellis perennis



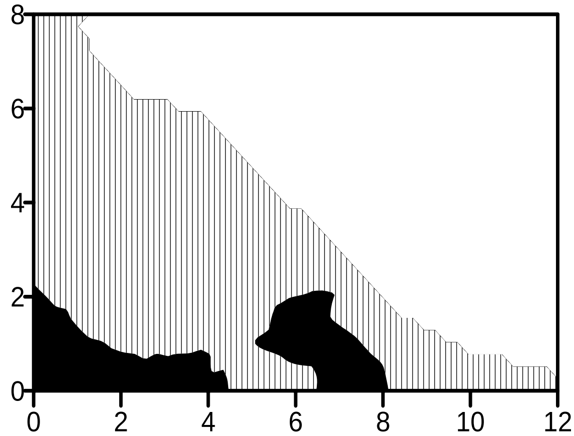
Brachythecium rutabulum



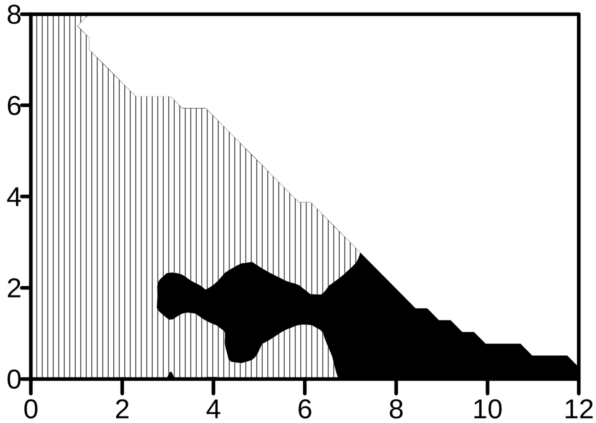
Briza media



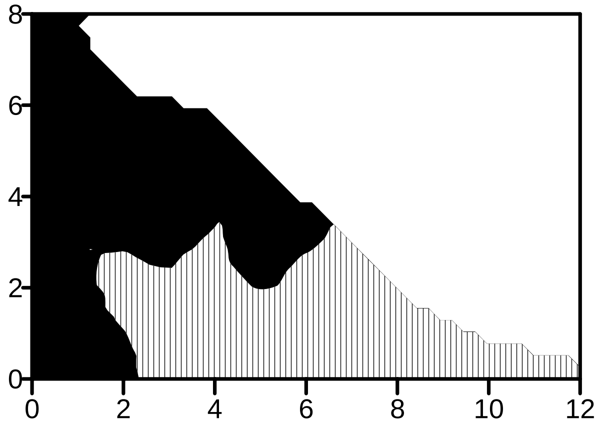
Bromus commutatus



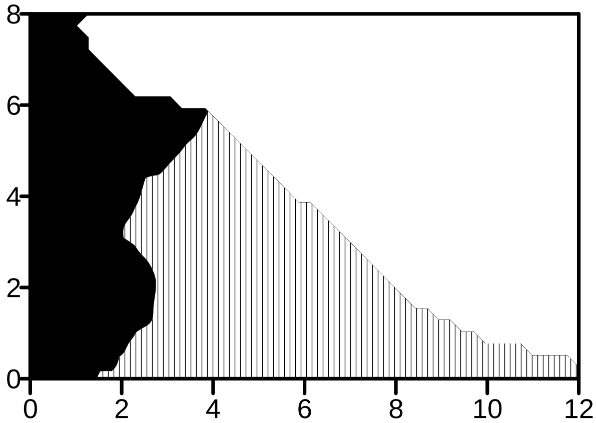
Bromus hordeaceus



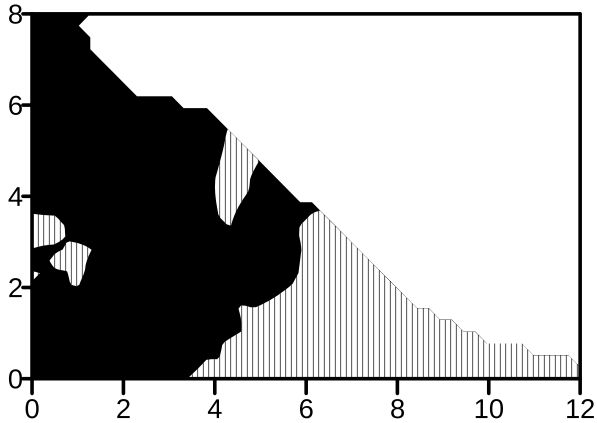
Bromus racemosus



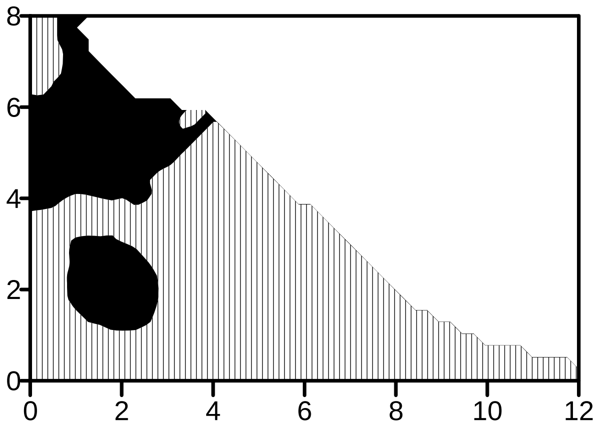
Calliergon cuspidatum



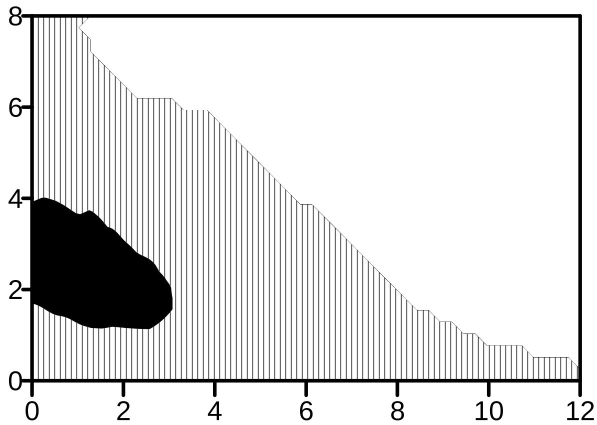
Caltha palustris



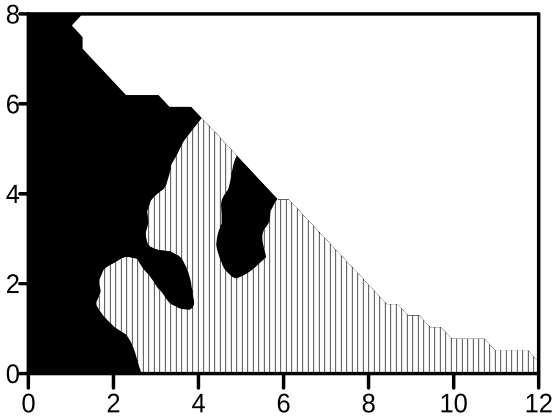
Cardamine pratensis



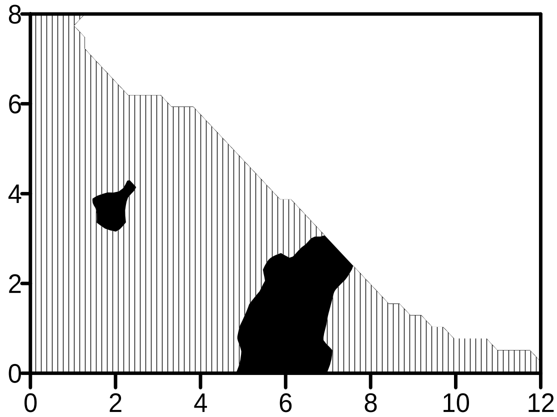
Carex acuta



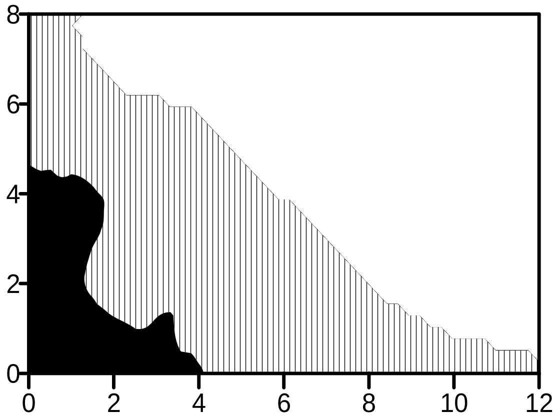
Carex acutiformis



Carex disticha



Carex flacca



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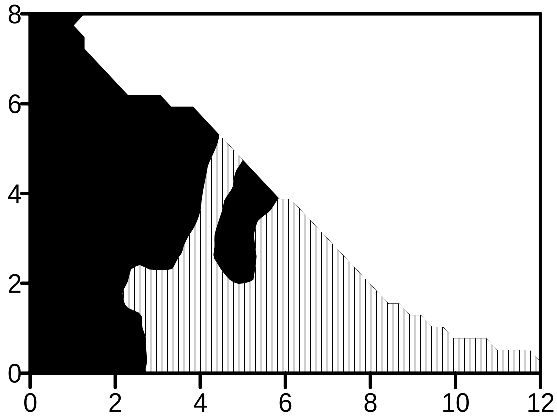

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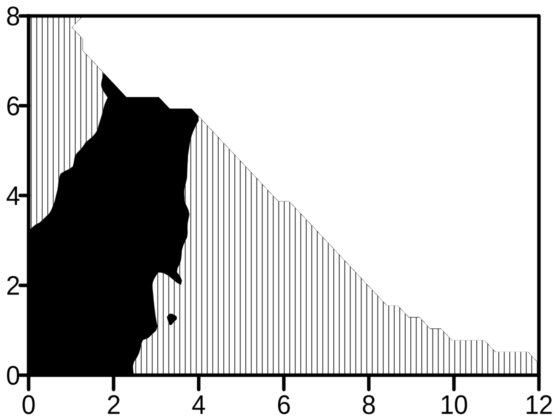

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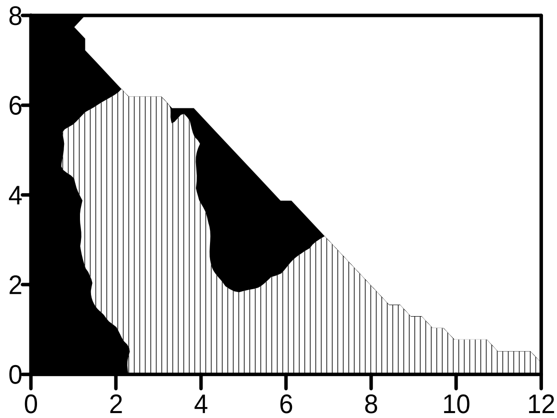
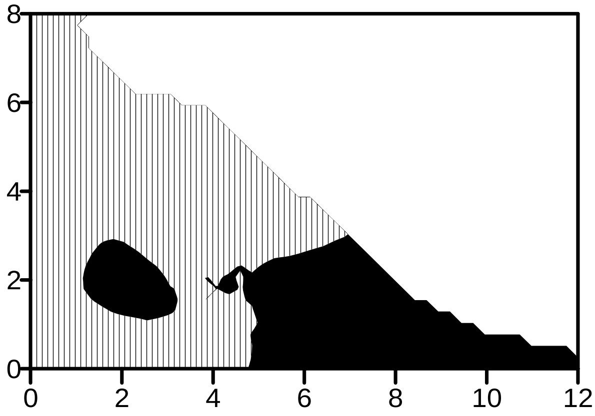
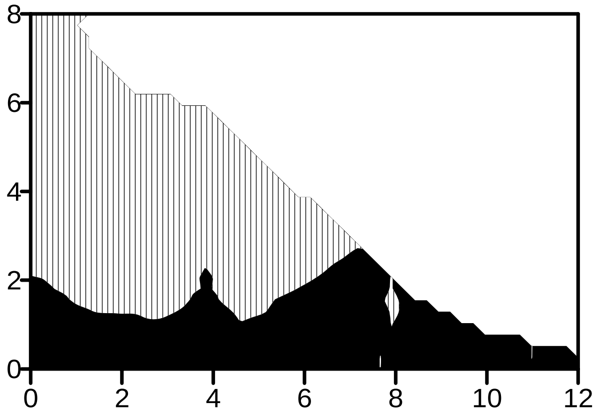


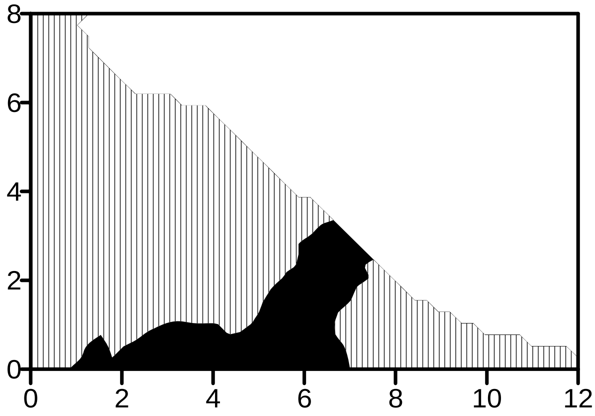
Carex riparia



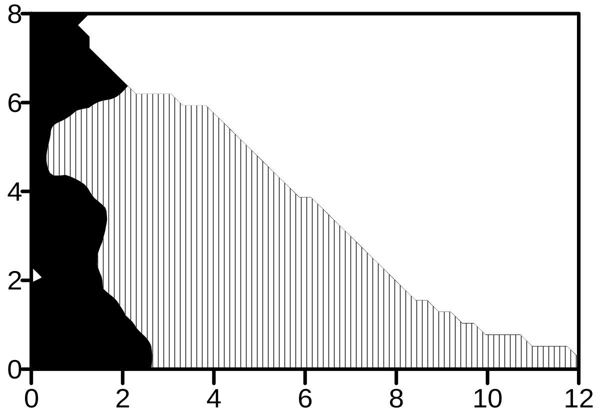
Centaurea nigra



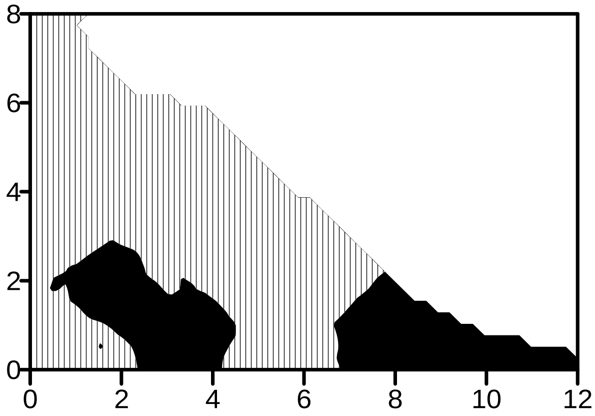
Cerastium fontanum



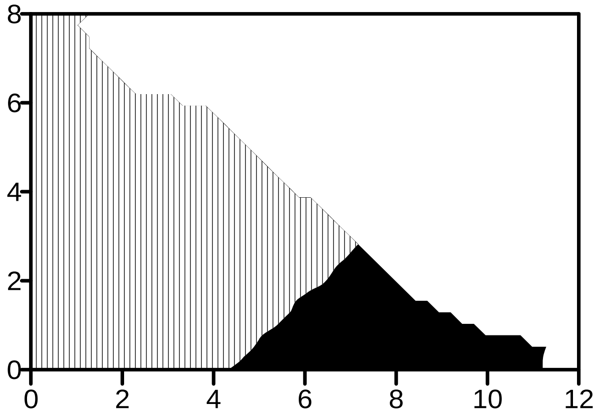
Cirsium arvense



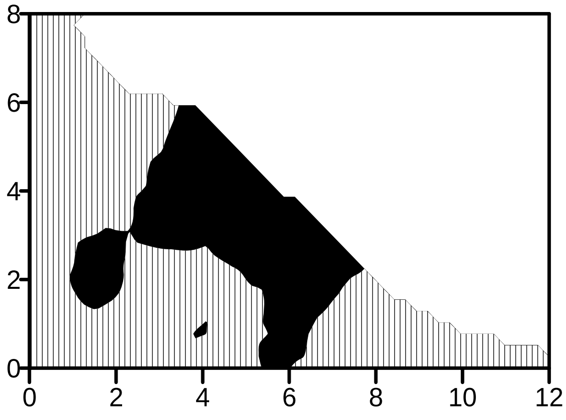
Cirsium palustre



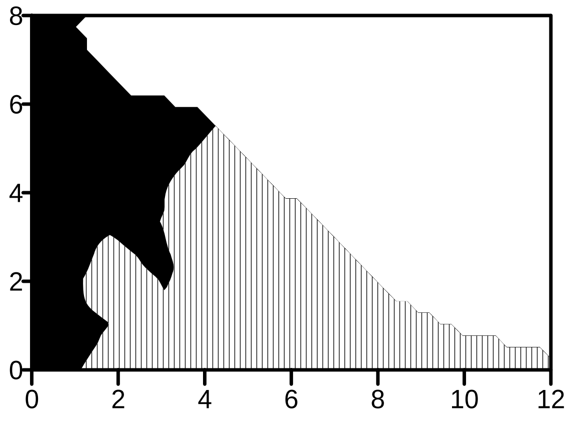
Cynosurus cristaus



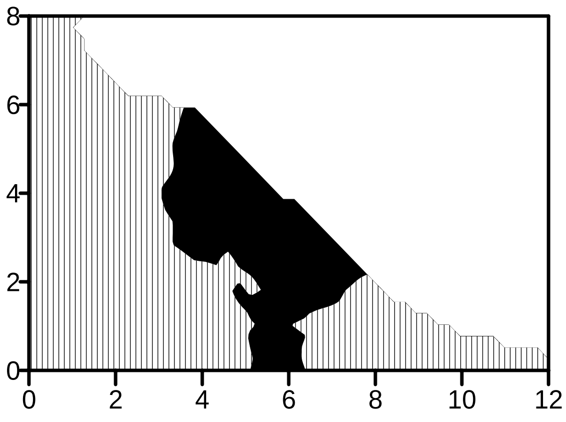
Dactylis glomerata



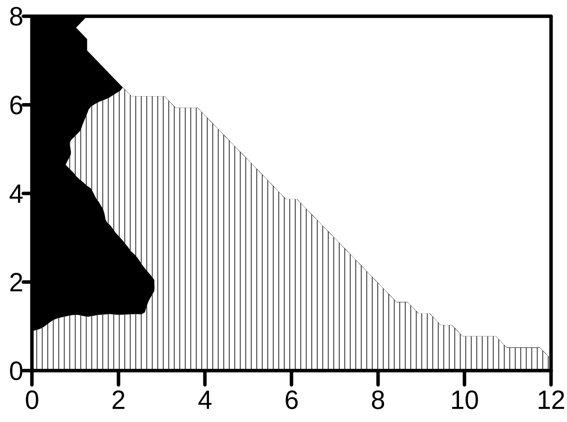
Deschampsia cespitosa



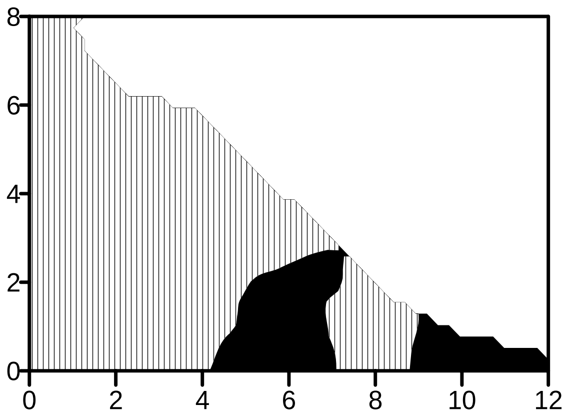
Eleocharis palustris



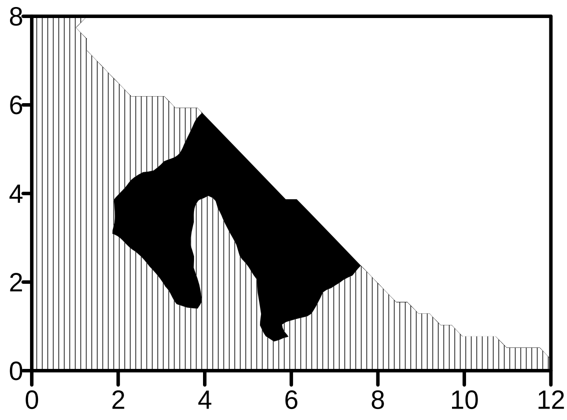
Elytrigia repens



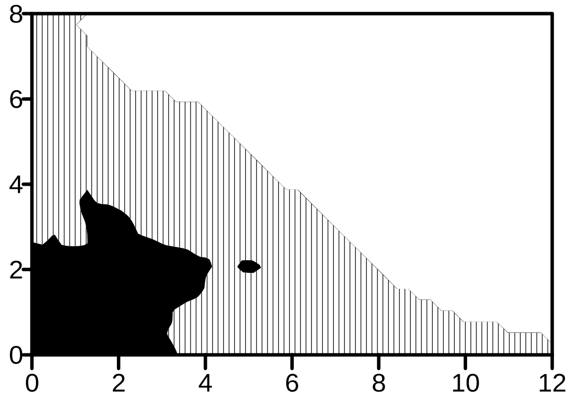
Equisetum palustre



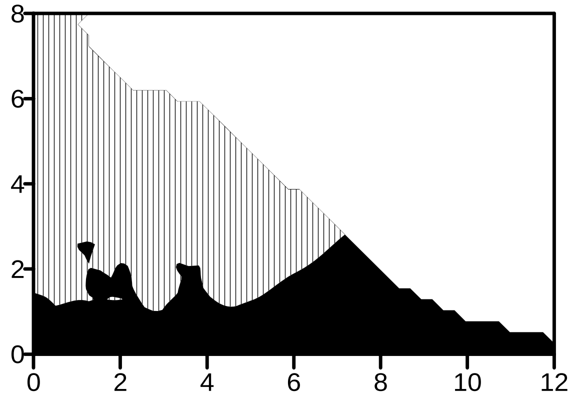
Eurhynchium praelongum



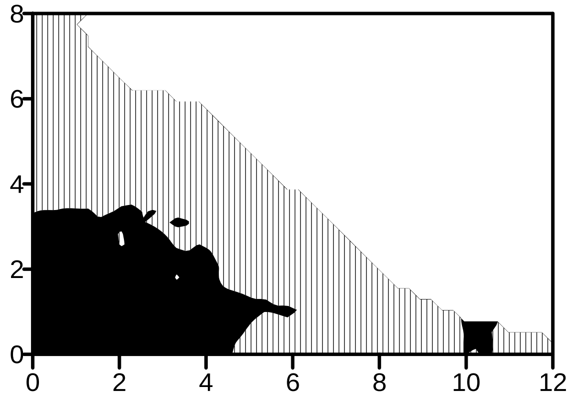
Festuca arundinacea



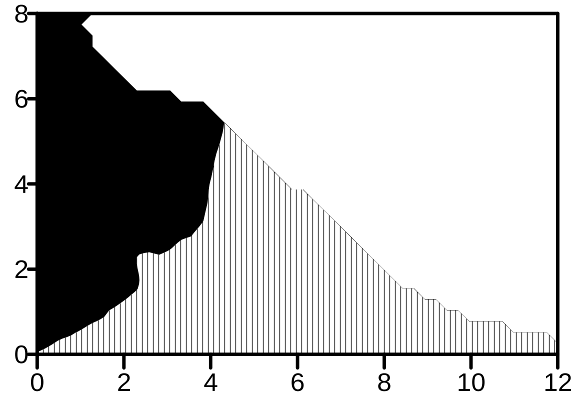
Festuca pratensis



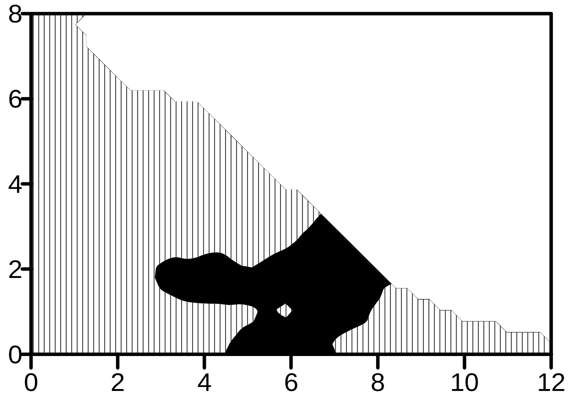
Festuca rubra



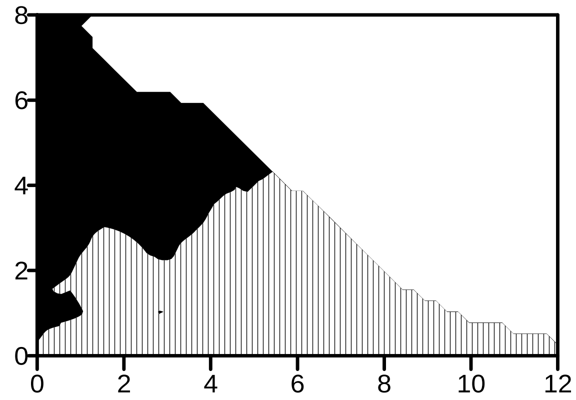
Filipendula ulmaria



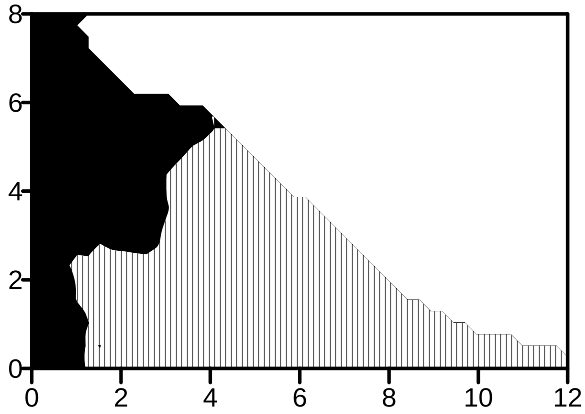
Galium palustre



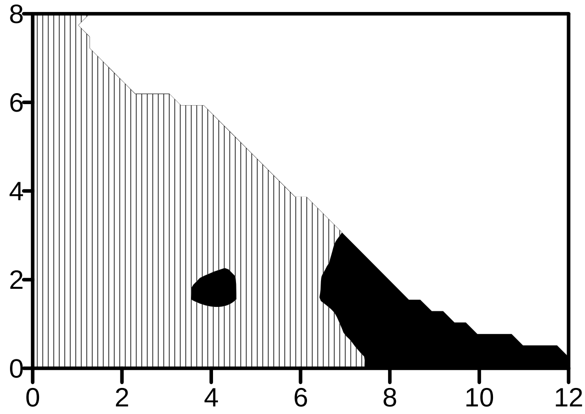
Galium verum



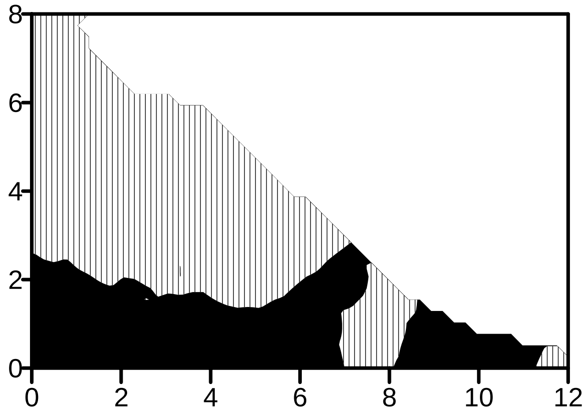
Glyceria fluitans



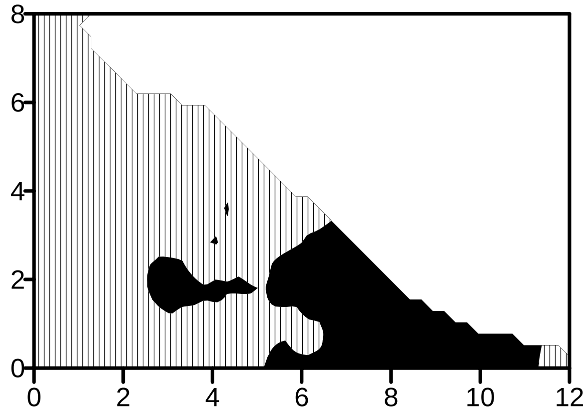
Gyceria maxima



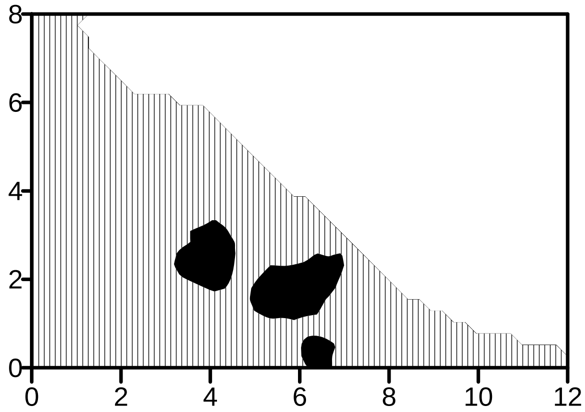
Heracleum sphondylium



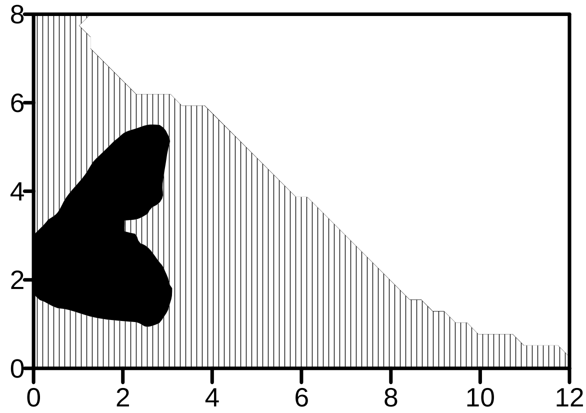
Holcus lanatus



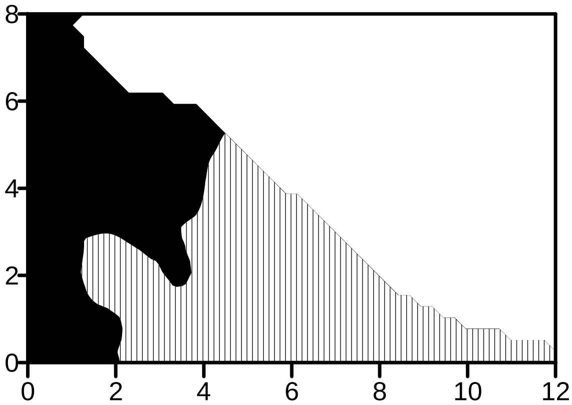
Hordeum secalinum



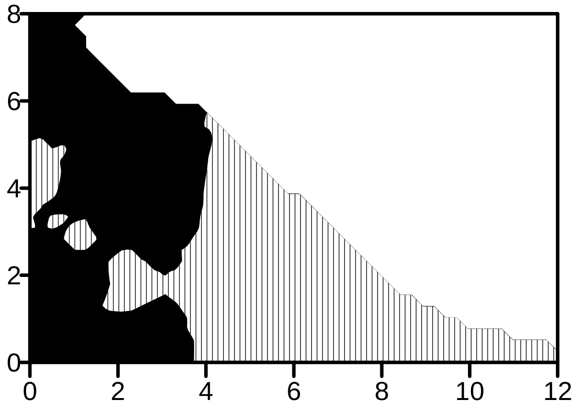
Hypochoeris radicata



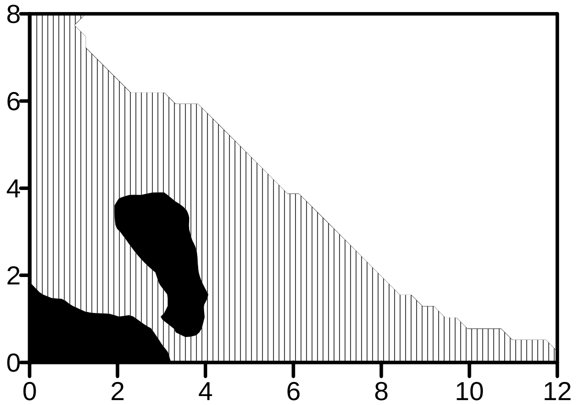
Juncus acutiflorus



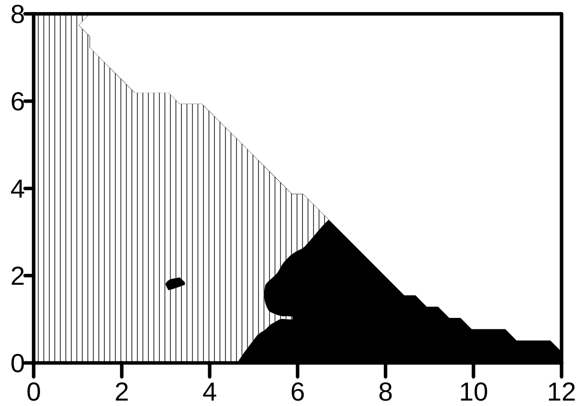
Juncus articulatus



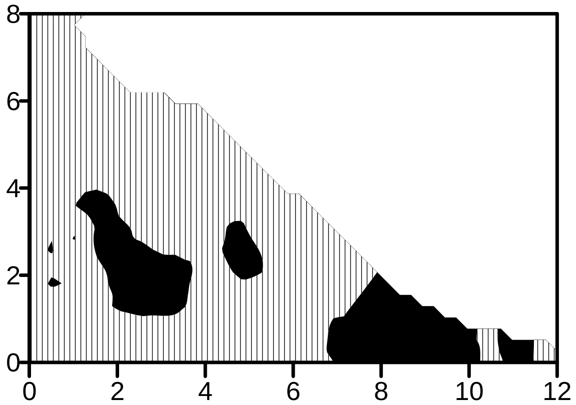
Juncus effusus



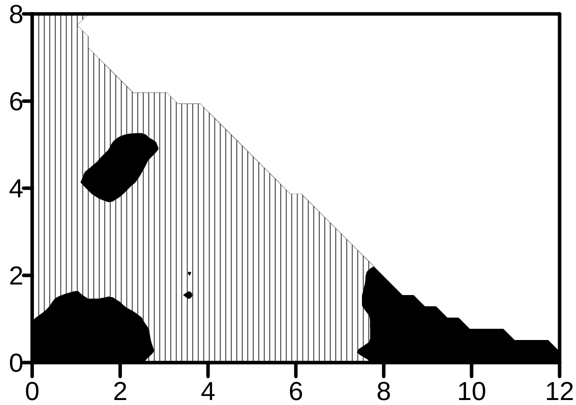
Juncus inflexus



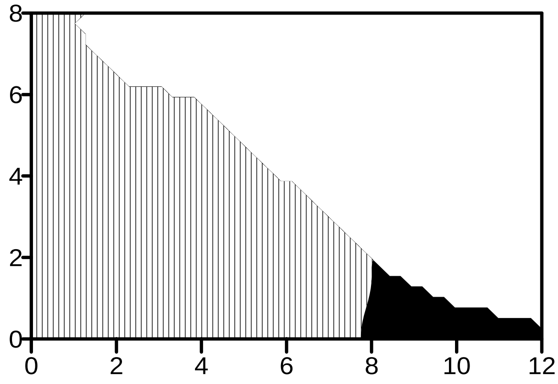
Lathyrus pratensis



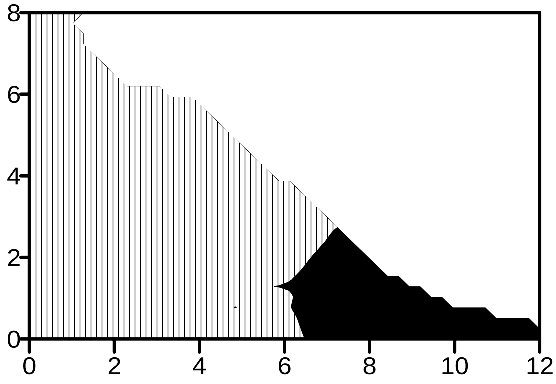
Leontodon autumnalis



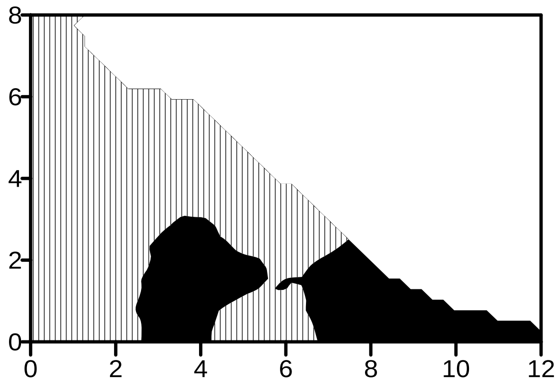
Leontodon hispidus



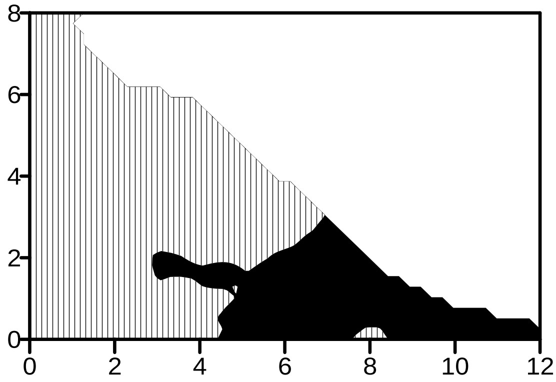
Leontodon saxatilis



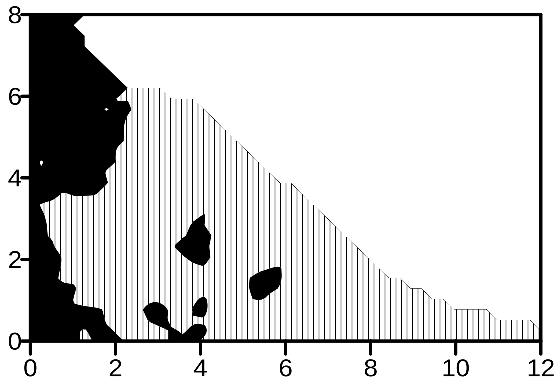
Leucanthemum vulgare



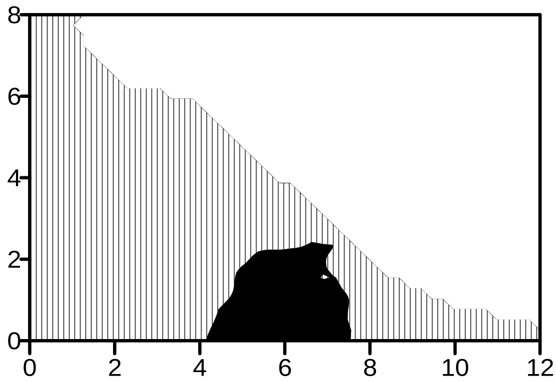
Lolium perenne



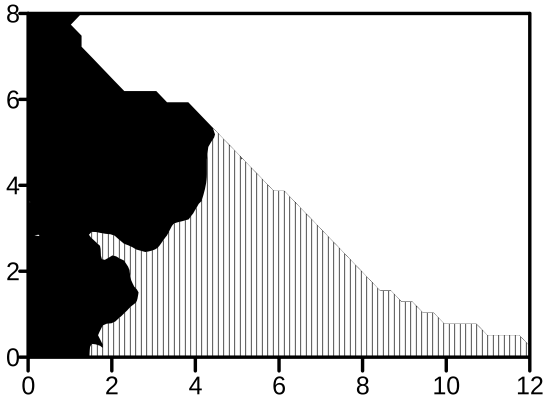
Lotus corniculatus



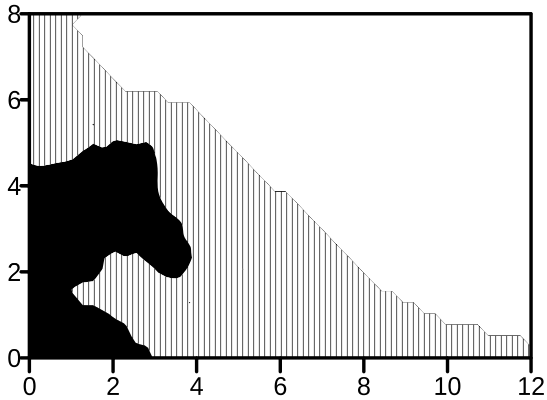
Lotus pedunculatus



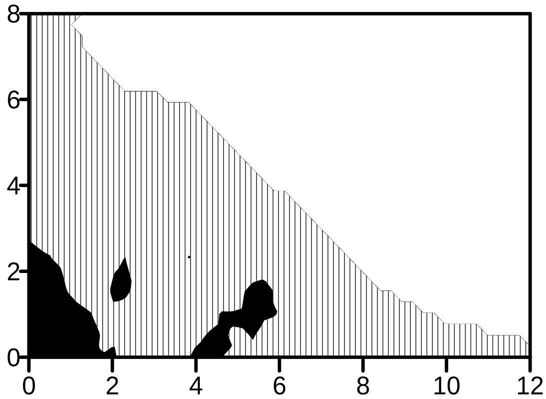
Luzula campestris



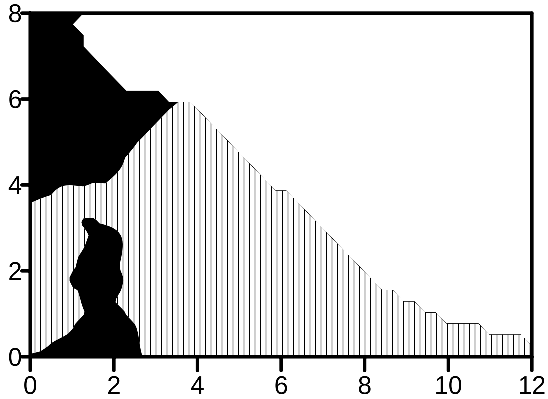
Lychnis flos-cuculi



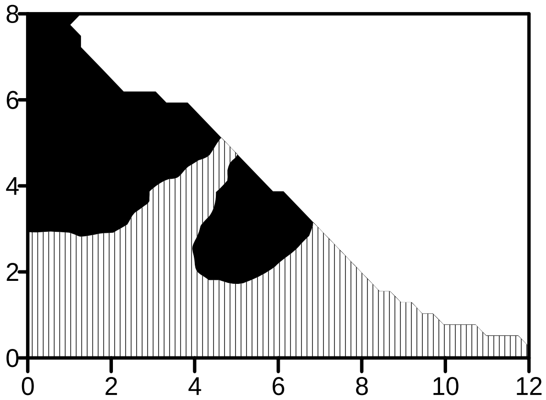
Lysimachia nummularia



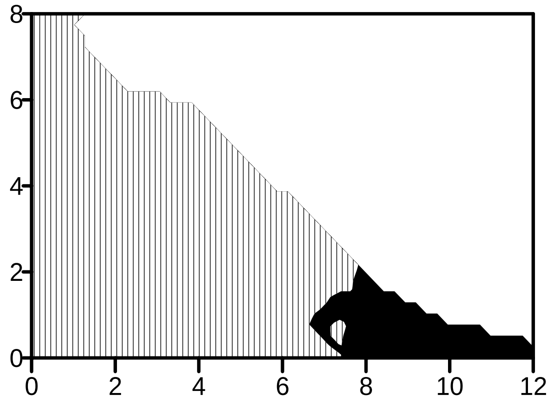
Myosotis discolor



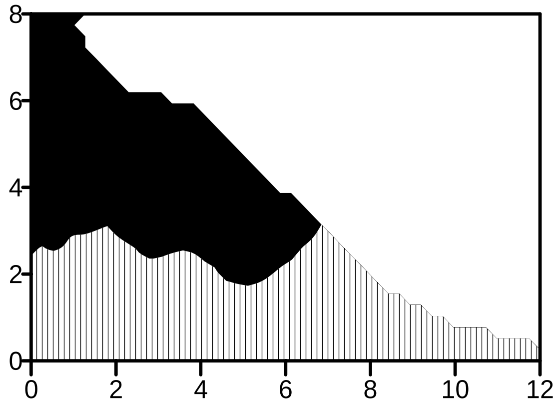
Myosotis laxa



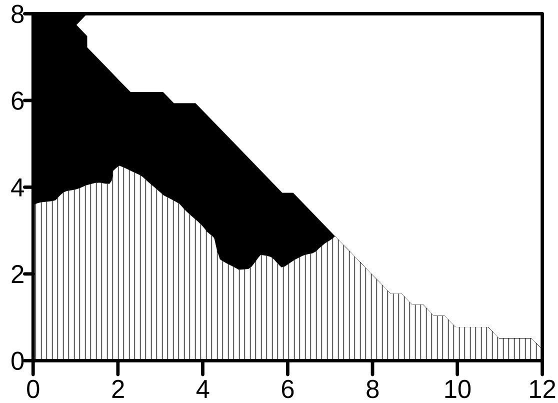
Oenanthe fistulosa



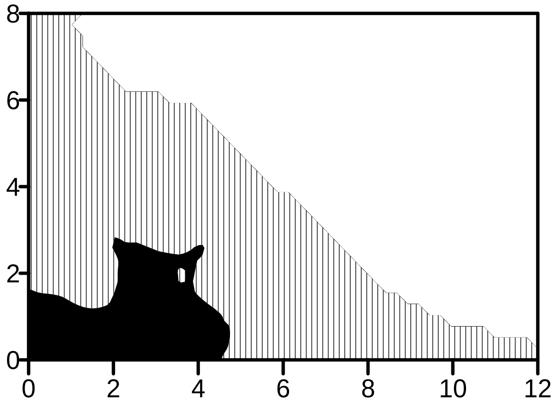
Ophioglossum vulgatum



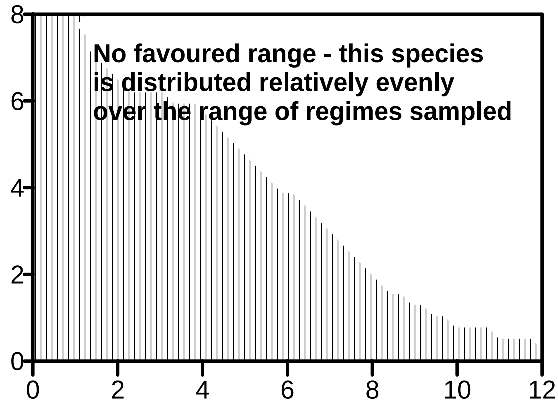
Persicaria amphibia



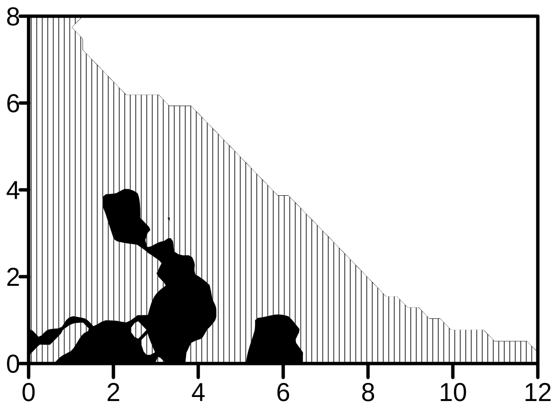
Phalaris arundinacea



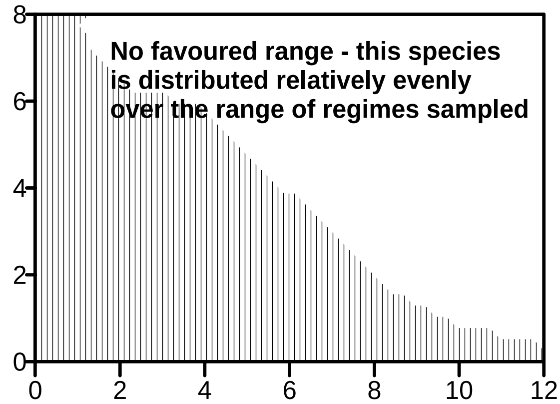
Phleum pratense



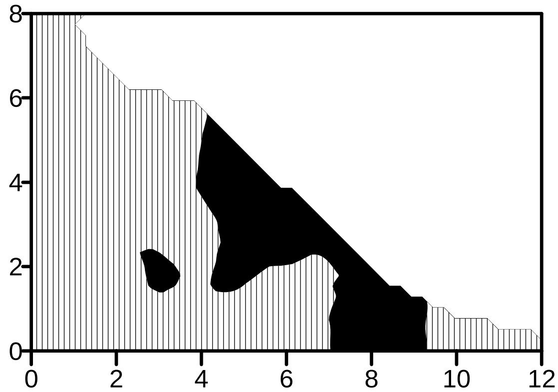
Plantago lanceolata



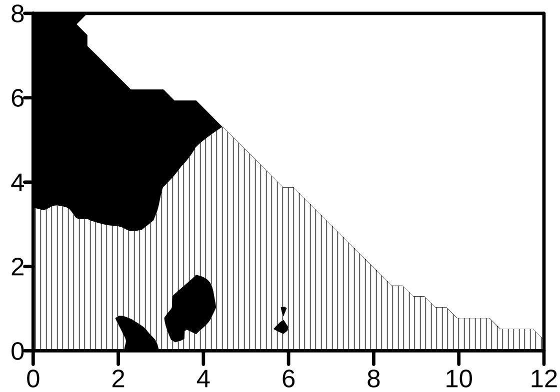
Poa humilis



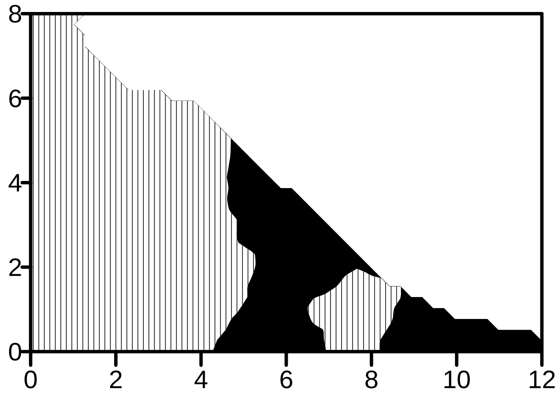
Poa pratensis



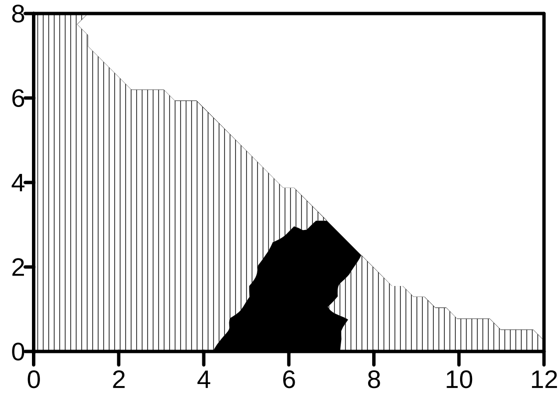
Poa trivialis



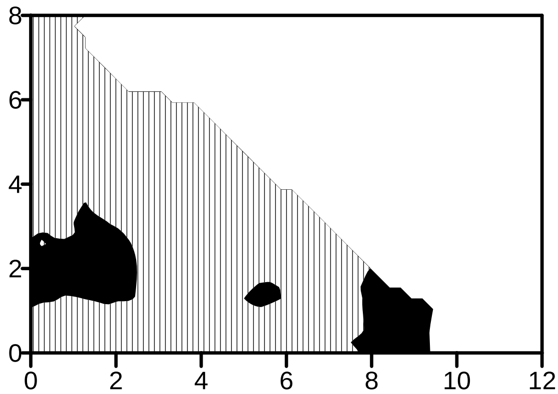
Potentilla anserina



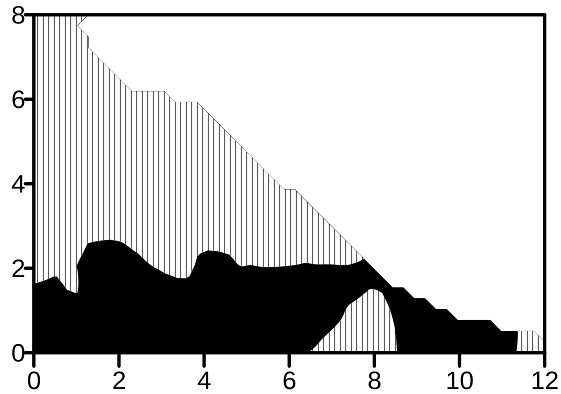
Potentilla reptans



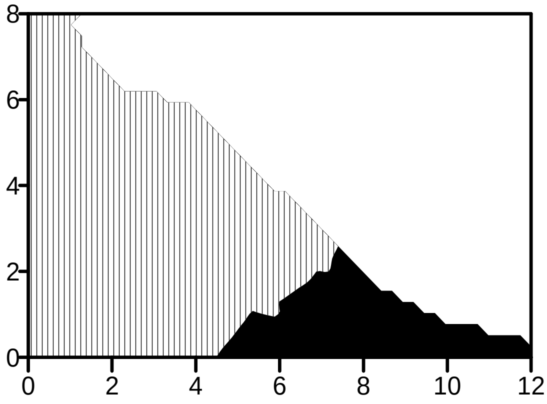
Primula veris



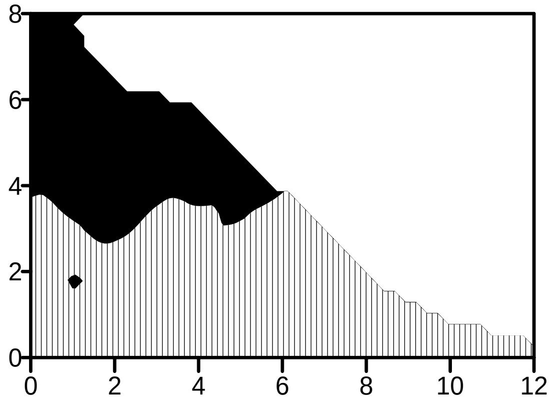
Prunella vulgaris



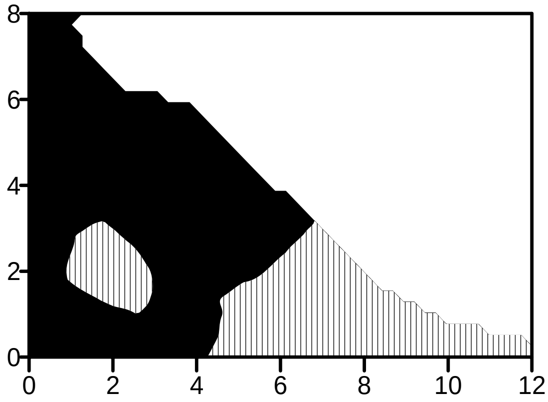
Ranunculus acris



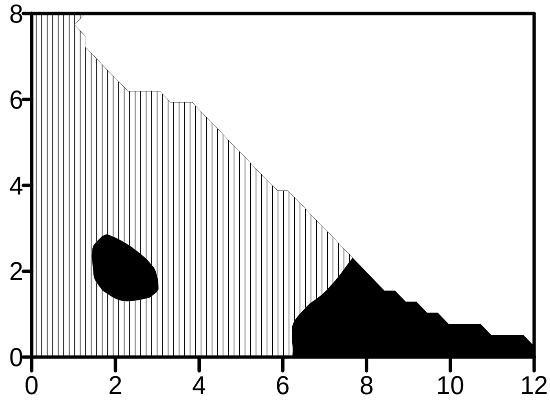
Ranunculus bulbosus



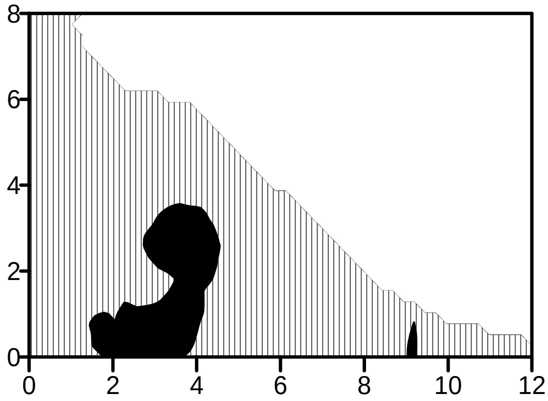
Ranunculus flammula



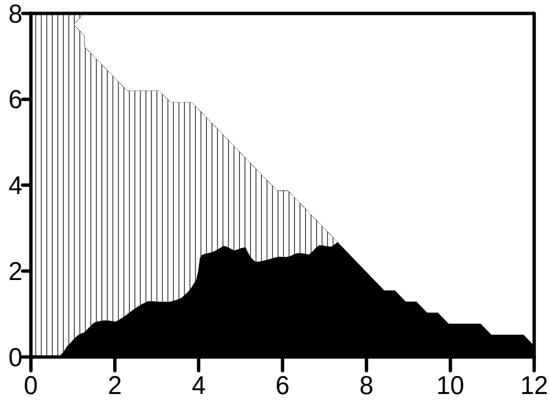
Ranunculus repens



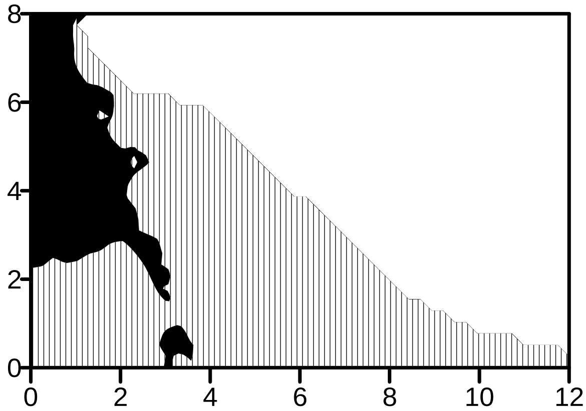
Rhinanthus minor



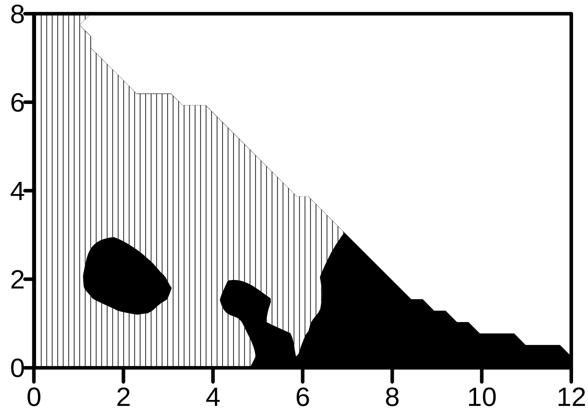
Rhynchostegium confertum



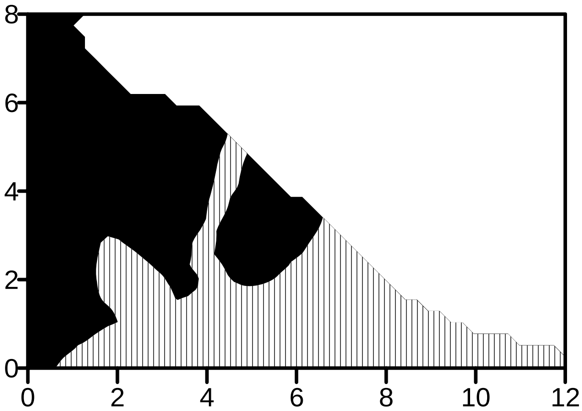
Rumex acetosa



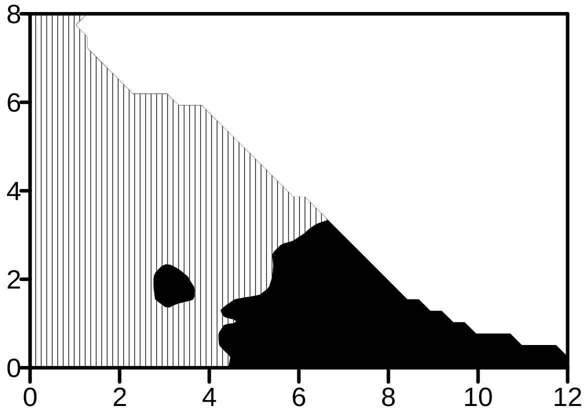
Rumex crispus



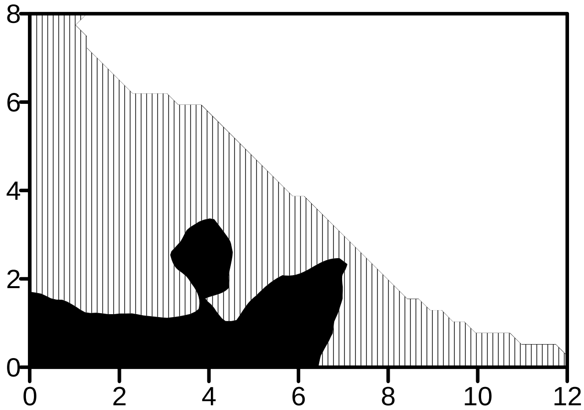
Sanguisorba officinalis



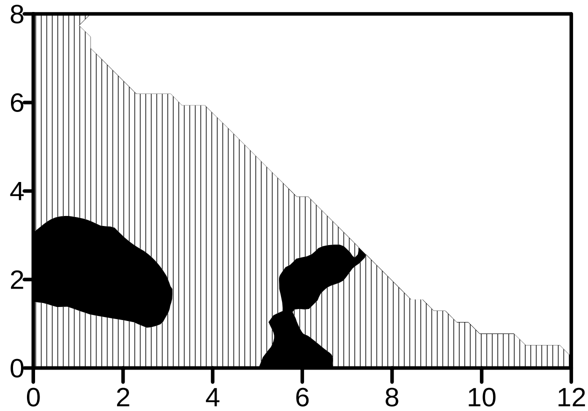
Senecio aquaticus



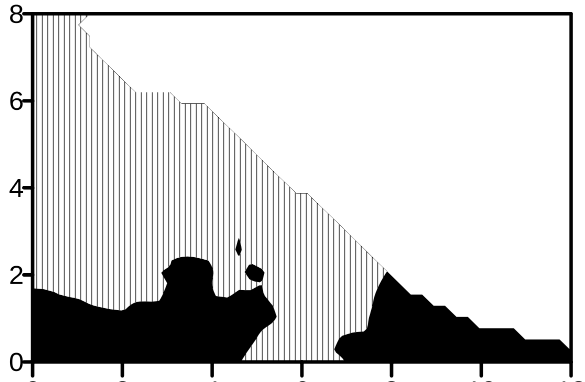
Silaum silaus



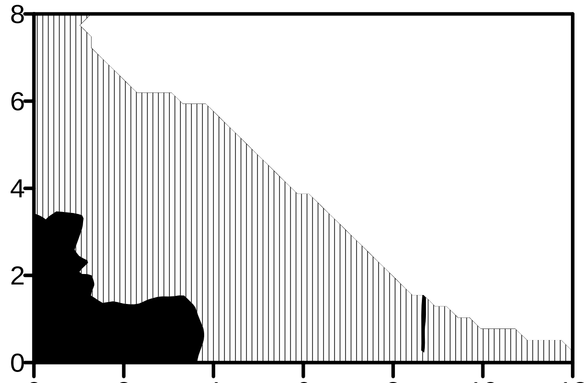
Stellaria graminea



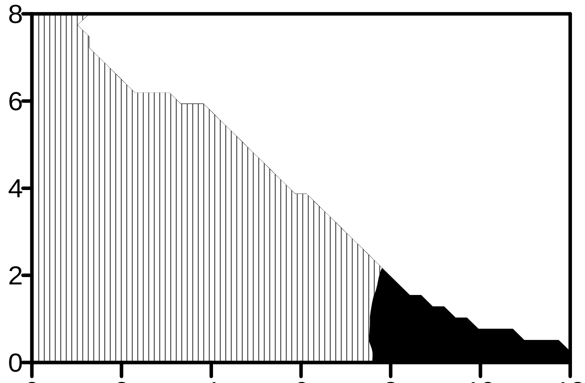
Succisa pratensis



Taraxacum officinalis



Thalictrum flavum



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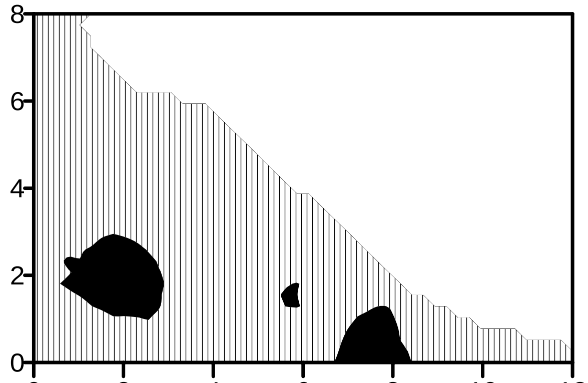

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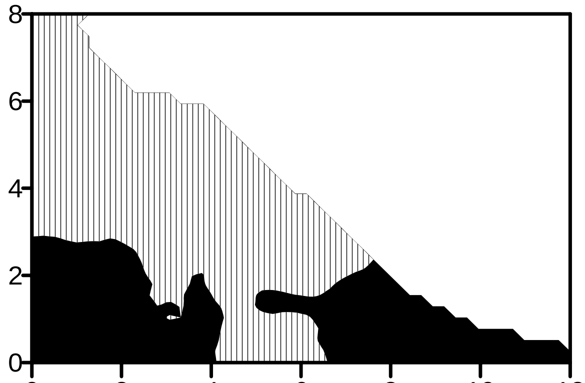

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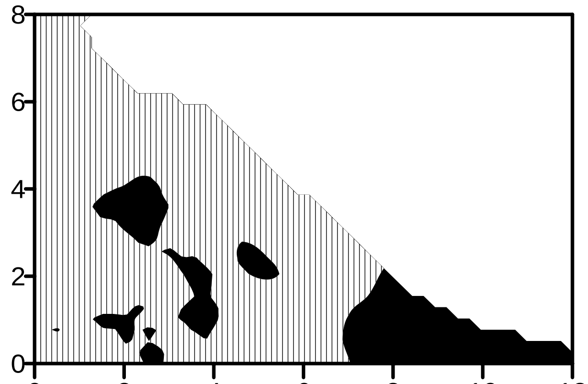

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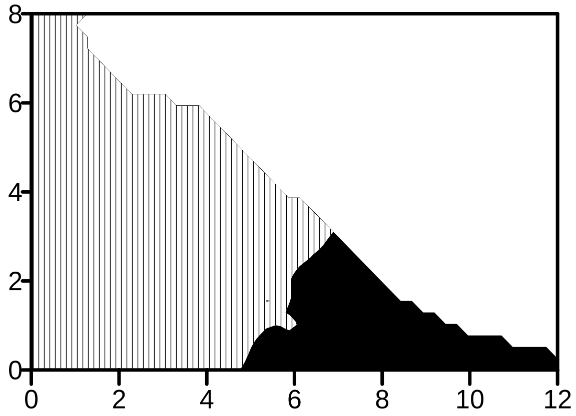
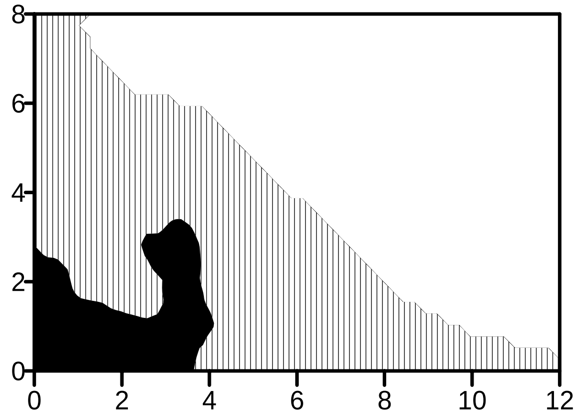
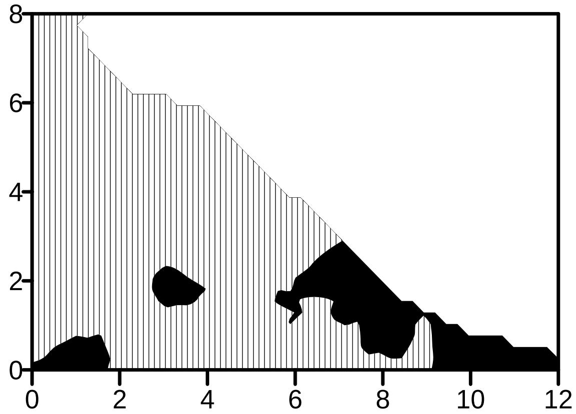


Trisetum flavescens



Veronica serpyllifolia



Vicia cracca

Appendix F: Soil Analysis Techniques

Soil preparation

The soil samples collected were air-dried at room temperature and milled to pass a 2mm mesh sieve.

Soil pH

20g of air-dried soil and 50ml distilled water are thoroughly stirred. Stir occasionally over 30 minutes, record the pH using a glass electrode.

Determination of extractable phosphorus

The method used is based on Olsen's Method. Phosphorus is extracted from soil at 20 ± 1°C with sodium bicarbonate solution of pH 8.5. The concentration of the blue complex produced by the reduction, with ascorbic acid, of the phosphomolybdate formed when acid ammonium molybdate reacts with phosphate is measured spectrophotometrically at 880nm.

Reagents

Polyacrylamide solution, 0.05% m/v (RSPUR 37) - Dissolve 0.125g of polyacrylamide in approximately 150ml of deionised water by stirring for several hours. When dissolved, dilute to 250ml with deionised water.

Sodium hydroxide solution, 50% m/v (RSPUR 38) - Dissolve 25g of sodium hydroxide in 50ml of deionised water, stirring well. Cool and store in a plastic bottle.

Sodium bicarbonate reagent, 0.5M (RSPUR 39) - Dissolve 210g of sodium hydrogen carbonate in deionised water, add 25ml of polyacrylamide solution and dilute to 5 litres with deionised water. Add sodium hydroxide solution (50%) until the pH measured with a pH meter is 8.5.

Method

2.5g of air-dried soil and 50ml of Sodium bicarbonate reagent (pH 8.5) are placed into a plastic bottle and shaken for 30 minutes. The solution is immediately filtered through a Whatman No. 2 filter paper and the filtrate retained for the determination of phosphate.

Determination reagents

Ammonium molybdate reagent, 1.2% m/v (RSPUR 40) - dissolve 6g of ammonium molybdate and 0.15g of antimony potassium tartrate in 300ml of deionised water, flowly add 74ml of conc. sulphuric acid, cool and dilute to 500ml with deionised water. Store in the refrigerator.

Ammonium molybdate reagent, 0.15% m/v (RSPUR 41) - Dilute 125ml of 1.2% m/v ammonium molybdate reagent to 1 litre. Prepare the on day of use.

Ascorbic acid solution, 1.5% m/v (RSPUR 42) - Dissolve 3.750g of ascorbic acid in 250ml of deionised water. Prepare on the day of use.

Phosphorus stock standard solution, 1000mg/l P (RSPUR 3) - dry potassium dihydrogen orthophosphate at 102°C for 1 hour and cool in a dessicator. Dissolve 1.0985g of the dried salt in deionised water and add 1.25ml conc. hydrochloric acid. Dilute to 250ml with deionised water. Store in the refrigerator.

Phosphorus working standard solution, 0 - 7 μg/ml of phosphorus (RSPUR 43) - Prepare on the day of use. Dilute 0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, and 0.7ml of stock standard to 100ml with sodium bircarbonate reagent.

Sulphuric acid, approx. 1.5M (RSPUR 44) - Add 80ml of conc. sulphuric acid to approx. 700ml of deionised water and make up to 1 litre with deionised water.

Preparation of Standard Graph

Pipette 5ml of each phosphorus working standard into a labelled 50ml beaker. Add 1ml of 1.5M sulphuric acid and swirl. Add 20ml of 0.15% ammonium molybdate reagent, 5ml of ascorbic acid solution, mix and allow to stand for 30 minutes. Measure the absorbance at 880nm.

Molybdate method for P determination

Pipette 5ml of the blank and each soil extract into labelled 50ml beakers. Add 1ml of 1.5M sulphuric acid and swirl. Add 20ml of 0.15% ammonium molybdate reagent, 5ml of ascorbic acid solution, mix and allow to stand for 30 minutes for colour to develop. Measure the absorbance at 880nm.

Basis for Calculation

R = (sample - blank) reading in μg/ml P

2.5g sample→50ml

↓

5ml used to produce R in μg/ml Phosphorus

R x (50/2.5) = μg/g Phosphorus = mg/kg Phosphorus

Calculation

Extractable phosphorus in mg/kg = R x 20

<u>Determination of extractable potassium</u>

Potassium is extracted from soil with M ammonium nitrate. The concentration of potassium in the extract is determined by flame photometry.

Reagents

1M Ammonium nitrate solution (RSPUR 46)- dissolve 400g of ammonium nitrate in deionised water and dilute to 5 litres.

Potassium stock standard solution 1000 mg/l Potassium (RSPUR 47)- dry approximately 2g of potassium nitrate at 102°C for 1 hour and cool in a dessicator.

Dissolve 1.293g in approximately 450ml of deionised water, add 1ml of conc. hydrochloric acid. Dilute to 500ml with deionised water and add 1 drop of toluene.

Potassium working standard solutions, 0-50 mg/l Potassium (RSPUR 48)- dilute 0ml,1ml, 2ml, 3ml, 4ml and 5 ml of 1000mg/l stock standard each to 100ml with 1M ammonium nitrate.

Method

10g of air-dried soil and 50ml of 1M ammonium nitrate solution are placed into a 100ml plastic bottle and shake for 30 minutes. Filter through No2 filter paper and retain the extract for the determination of potassium. Carry out a blank extraction omitting the soil.

Determination

Set the Flame Photometer according to the instructions to measure potassium emission and adjust to produce zero and maximum readings aspirating the 0 and 50 mg/l of potassium standard solutions.

Aspirate the intermediate standard solutions and construct a graph relating meter readings to mg/l of potassium. Aspirate the blank and sample extracts and record the meter readings.

Calculation

Read from the standard graph the mg/l of potassium equivalent to the meter readings of the blank and sample extracts.

Multiply the sample - blank value by 5 to give the result in mg/kg of extractable potassium in the sample (i.e. 10g extracted in 50ml).

Determination of Total Nitrogen

The method used is based on Kjeldahl's Method. Organic N in the sample is converted to ammonium-nitrogen by digestion with sulphuric acid and ammonia liberated with sodium hydroxide.

Digestion Reagents

KJELTABS C catalyst tablets (contain 5g K_2SO_4 + 0.1g $CuSO_4$*$5H_2O$)

Sulphuric acid 98% (1.84sp.gr).

Digestion Method

5g of air-dried soil into digestion tube and add 2 Kjeltabs C tablets. Put 4-8 glassbeads into each tube and add 20ml of concentrated sulphuric acid. Place the digestion tubes in the digestion tube holder, put the suction module with fitted gaskets on the digestion tubes and place tubes into preheated Digestion unit. Heat the flask for at least 1 hour or until the solution clears. Switch the heat off on the Digestion Unit. After about 15 minutes take the tubes out of the Unit and leave on the rack to cool for at least 30 minutes. Samples are ready for distillation. Carry out a blank digest.

Preparation of water digests

Pipette 10ml of water sample into a digestion tube and add 10ml of ethanol and add 2 Kjeltabs C tablets. Put 4-8 glass beads into each tube and add 20ml of concentrated sulphuric acid using dispenser.

Sample distillation

Distillation reagents

1% Orthoboric Acid (Boric acid) 10g of boric acid made up to 1 litre with distilled water

Mixing indicator SHER

Sodium hydroxide 40% m/v

Distillation method

Fill the container with NaOH (at least half). Fill the second container with deionised water. Turn mains water tap on. Make sure that drain pipe is placed into the drain. Switch the Distillation Unit on. Aspiration valve should be in YES position. Wait 5-10 minutes for unit to warm up. Add 50ml of deionised water to digestion tube. Add 100ml of Boric acid to 500ml conical flask and add 3-5 drops of SHER indicator. Place receiver in the right position on the distillation unit. Make sure that the tube is in the liquid. Add sodium hydroxide solution 60-90ml. The amount of NaOH solution must be chosen so that a colour change to brown or blue is clearly visible. Set the time for 3 minutes. Press the Start switch. Turn the aspiration valve to the NO position. When distillation has finished take conical flask off (it should have green colour). Sample is ready for titration. Put the aspiration value in YES position. Take off the digestion tube using tongues provided. Repeat the procedure until all samples have been distilled.

Titration

Titration reagents

Sulphuric acid 0.1M, 0.01M, <u>0.005M</u> or any other strength. This will depend on amount of Nitrogen expected. Titrate the solution in the receiver with sulphuric acid to a change of colour

green → blue → grey-brown

Titration is first performed rapidly until there is a change of colour to blue (1st point change = warning point) and then titration is continued cautiously until there is a change of colour to grey-brown (2nd point of change = end point of the titration).

Basis of the calculation

1 H+	= 1 NH_4+
98g of H_2SO_4	= 28g N
1M H_2SO_4	= 28g N
g N/kg soil	= T * M *28/wt of soil

mgN/l of water sample = T * M * 28 *1000/sample volume

where:	T	- T_s - T_b
	T_s	- mls of H_2SO_4 in sample titration
	T_b	-mls of H_2SO_4 in blank titration
	M	- molarity of H_2SO_4

% N = g N/kg / 10

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Appendix G

Table G1. Mean values for soil nutrient determinants by site

Site	**pH** (air-dried soil reformed to a paste in distilled water)	**Extractable phosphorus (mg/l)**	**Extractable potassium (mg/l)**	**Total Nitrogen (g/l)**	**Number of samples**
Cricklade*	6.30	11.79	86.75	6.29	20
East Harnham*	6.24	4.88	51.34	9.31	10
Moorlinch	5.77	1.33	55.47	7.30	25
Mottey Meadow	5.15	3.81	130.75	5.88	18
Portholme*	5.99	4.67	95.89	4.70	20
Stonygillfoot	5.91	6.17	74.70	5.89	11
Upton Ham*	5.05	12.95	114.47	4.20	25
Wet Moor	5.18	5.93	127.45	9.459	20

*Those sites experiencing floods from major rivers (at least over part of their area.)

Table G2. Mean values for soil nutrient determinants by community type, with standard errors of the mean.

Botanical community (end group)	**pH** (air-dried soil reformed to a paste in distilled water)	**Extractable phosphorus (mg/l)**	**Extractable potassium (mg/l)**	**Total Nitrogen (g/l)**	**Number of samples**
MG3	5.9 ±0.1	6.5 ±0.9	79 ±8.3	5.4 ±0.8	6
MG4	5.8 ±0.1	4.1 ±0.5	86 ±7.4	5.1 ±0.3	23
MG4+	5.5 ±0.1	8.3 ±0.9	110 ±3.0	4.8 ±0.3	24
MG8~	6.2 ±0.1	5.1 ±1.0	56 ±4.1	8.5 ±0.5	15
MG8 *Cx*	5.2 ±0.1	2 ±0.3	72 ±9.9	5.7 ±0.2	33
Ag/Cx *C.distans*	6.5 ±0.1	1.9 ±0.2	61 ±2.9	9.4 ±0.4	6
Ag/Cx	5.3 ±0.1	5.3 ±0.6	120 ±4.5	9.1 ±0.3	23
MG13	5.8 ±0.2	17 ±2.1	112 ±4.5	5.4 ±0.3	22

Appendix H

End Group descriptions for the 3904 TWINSPAN

Excluding the two tall-herb fen End Groups, the vegetation types characterised in the analysis represent five major sorts of grasslands, equivalent to different phytosociological alliances on a European level: the sub-montane meadows of the Polygono-Trisetion (End Group 1), the lowland dry pastures and meadows of the Cynosurion (3, 5 & 6), the lowland flood-meadows of the Alopecurion (2, 4 & 7), the wet grasslands of the Calthion (8, 9 & 10), the vegetation types of less stable inundated habitats in the Lolio-Potentillion (11 & 12). Of these 12 end-groups, 10 can be fairly readily accommodated in the vegetation types characterised in the NVC and the remaining 2 are part of a complex of wet grasslands already outlined in Rodwell et al. 1998.

End Group 1

Moderately tall hay-meadow vegetation limited to northern upland fringe localities and with a prominent contingent of colourful dicotyledonous herbs including *Geranium sylvaticum*, sometimes with *G. pratense* at lower altitudes and around the field boundaries which are typically dry limestone walls. Also characteristic are *Euphrasia officinalis* agg. and *Alchemilla* spp.. Among the grasses, *Conopodium majus Anthoxanthum odoratum* (an early conspicuous flowerer) and *Trisetum flavescens* are especially distinctive, with *Bromus hordeaceus* ssp. *hordeaceus* perhaps indicating sites ploughed during WW2. *Lolium perenne* is typically uncommon. Although this vegetation shares with lowland flood meadows the presence of and Filipendula ulmaria are characteristically poorly represented. This *Sanguisorba officinalis, Centaurea nigra* vegetation is equivalent to MG3 *Anthoxanthum-Geranium* grassland, the British representative of the Polygono-Trisetion alliance of traditionally-managed sub-montane meadows found in upland valleys throughout central and northern Europe. Only British examples of this alliance have statutory protection under the EU Habitats Directive, though this is not a fair reflection of the interest and value of such grasslands elsewhere in Europe.

End Group 3

Rather open, moderately productive grasslands with *Lolium perenne* and *Dactylis glomerata* partly replacing *Agrostis capillaris* and *Anthoxanthum odoratum* characteristic of the swards of End groups 1 and 2. Among the rich contingent of dicotyledons, *Trifolium pratense, Rhinanthus minor, Ranunculus bulbosus, Leontodon autumnalis* and *L. taraxacoides* are especially distinctive, also wth *Leucanthemum vulgare, Lathyrus pratensis* and occasional *Filipendula ulmaia, Heracleum sphondylium* and *Arrhenatherum elatius*. Silaum silaus is also quite common. This is convincing MG5a, the *Lathyrus* sub-community of *Centaurea-Cynosurus* grassland, the major British example of the less improved lowland hay-meadows of north-west Europe included in the Cynosurion alliance.

End group 5

A moderately tall, rather dry grassland geneally similar to the swards in End group 3 but with much more frequent *Alopecurus pratensis* and often with *Festuca rubra* and *Hordeum secalinum* prominent and *Avenula pubescens, Pleum bertolonii* and *Festuca arundinacea* occasional. The herb contingent is often species-rich and colourful with preferentially frequent *Primula veris, Galium veru, Achillea millefolium, Filipendula vulgaris* and

Potentilla reptans. Some of these preferentials are suggestive of MG5b the *Galium verum* sub-community of *Centaurea-Cynosurus* grassland and this could be seen as a *Hordeum secalinum* variant of that vegetation type. Species such as *H. secalinum, Festuca arundinacea* and *Elytrigia repens* are characteristic of Cynosurion grasslands on reclaimed coastal marshes (Rodwell et al. 1998).

End group 6

This grassland is not so species-rich or luxuriant as other of the drier grasslands included here and it has the general appearance of a damp meadow with a grassy sward in which *Anthoxanthum odoratum* remains frequent, *Phleum pratense* and *Poa pratensis* are occasional but *Alopecurus pratensis* and *Agrostis stolonifera* are uncommon. Small herbs such as *Ranunculus repens, Cerastium fontanum* and *Stellaria graminea* are common, the first often abundant, frequently with an extensive moss carpet in which *Brachythecium rutabulum* and *Eurhynchium praelongum* are prominent. This vegetation has much in common with MG6 *Lolium-Cynosurus* grassland, both the Typical and *Anthoxanthum* sub-communities, but the high frequency of *Filipendula ulmaria* is very distinctive and puts it close to the *Iris* variant recognised by O'Sullivan (1968) from wet valleys in Eire. The *Lolium-Cynosurus* grassland includes often somewhat improved pastures from trhoghout the lowlands of western Europe.

End group 2

Tall and bulky swards by mid-season when bigger dicotyledons, notably Sanguisorba officinalis which has its peak of occurrence in this vegetation, overtop the rich mixture of grasses and smaller forbs. Earlier in the season, it is rosette plants among the latter which tend to be most conspicuous, some such as *Centaurea nigra* putting up flowering stems among the grasses, of which *Lolium perenne* and *Festuca rubra* are often prominent. *Silaum silaus* is very characteristic here and, less commonly, *Fritillaria meleagris*. This is classic MG4 *Alopecurus-Sanguisorba* grassland which includes the richer of our traditionally-managed lowland alluvial flood-plain meadows. In the NVC, this vegetation was placed in the Cynosurion alliance but more recent revisions of European vegetation types would include it with the Alopecurion grasslands.

End group 4

These are more species-poor and grassy swards than the above with *Alopecurus pratensis* especially prominent and, beneath, often with much *Poa trivialis* and *Agrostis stolonifera*, when the vegetation can be altogether shorter. Though Sanguisorba is still present, the variety oif colourful herbs is much reduced and only *Ranunculus acris* and *Rumex acetosa* remain very frequent, with no additional referentials. This vegetation can be considered an impoverished variant of MG4 *Alopecurus-Sanguisorba* grassland – what Dutch phytosociologists would call a Rompgemeenschap or basal community of the Alopecurion alliance.

End group 7

This includes swards strongly dominated by the robust grasses *Alopecurus pratensis a*nd *Festuca pratensis*, often with *Bromus racemosus. Phleum pratense* and some *Deschampsia cespitosa* and with a poor contingent of colourful herbs. Compared with End groups 2 and 4, *Festuca rubra* and *Holcus lanatus* are less prominent but *Agrostis stolonifera* and *Ranunculus repens* are more important constuituents of the sward. In the NVC, thi kind of vegetation is subsumed among a compendious group of grasslands, most of which are species-poor leys or recreational swards. It is clear hat this particular community, called there MG7C *Lolium-*

Alopecurus-*Festuca* grassland is worthy of elevation to community level. It is characteristic of seasonally flooded alluvium and can be included in the Alopecurion alliance.

End group 8

This includes low to moderately tall swards with a very variable grassy component in which *Alopecurus pratensis* in particular is very scarce compared with the meadow communities described above. Taller tussocky Junci are not abundant but there is often some *Juncus articulatus, Filipendula ulmaria* and *Carex hirta* and less frequently, *C. nigra* and *C. disticha*. *Eleocharis palustris, Caltha palustris* and *Senecio aquaticus* are common, *Cirsium palustre, Lychnis flos-cuculi, Geum rivale, Pulicaria dysenterica, Lotus pedunculatus, Galium uliginosum* and *Iris pseudacorus* preferential at lower frequencies. *Calliergon cuspidatum* is quite common with *Climacium dendroides* occasional. Although, within the NVC, the definition of MG8 *Caltha-Cynosurus* grassland is recognised to be unsatisfactory (Rodwell et al. 1998), this vegetation come close to the published definition of the community.

End group 9

Compared with End group 8, with which this vegetation has much in common in its grass and small herb contingent, there are frequent tussocks here of the larger rushes *Juncus effusus* and *J. acutiflorus* and a low lawn of *Carex nigra, C. panicea* and *Agrostis canina. Cirsium dissectum* has it peak of occurrence here and can be locally prominent. This kind of vegetation, together with the previous End group 8 and also 10 and 11, and similar vegetation described from previous surveys (Cox & Leech 1995), need a thorough reappraisal but, among them all, this is closest to the Ranunculo-Senecionetum (previously the Senecioni-Brometum) described from The Netherlands, most recently by Schaminee et al. (1996). This association of the Calthion alliance is especially characteristic of flooded sites where there is considerable variation in the timing and length of inundation.

End group 10

This distinctive group, from Moorlinch only, is similar to the previous vegetation but with more frequent *J. inflexus, J. articulatus, Carex disticha* and, especially distinctive here, *C. distans*, and the preferentials *Eleocharis uniglumis, Festuca arundinacea* and *Juncus subnodulosus*. *Lolium perenne* is unusually frequent for a wet unimproved grassland but grasses as a whole are not the dominant element in the vegetation. This is probably best seen as a variant of the Ranunculo-Senecionetum.

End group 11

Agrostis stolonifera and *Ranunculus repens* are very frequent here in low patchy swards, the latter being often very abundant. *Alopecurus geniculatus* and *Glyceria fluitans* are common, the latter a good preferential, in an extensive carpet of *Calliergon cuspidatum*. Among the various sedges found in the wetter communities, *Carex nigra* remains especially frequent and is locally dominant in dense patches and *Glyceria maxima* can be prominent too. *Polygonum amphibium, Potentilla anserina* and *Ranunculus flammula* are preferential and *Oenanthe fistulosa*, a characteristic plant of the three wettest vegetation types, is becoming frequent. This kind of sward may be part of an *Agrostis stolonifera-Carex nigra* community which Rodwell et al. (1998) reported from various kinds of wet pastures and damp hollows in coastal as well as inland habitats. It was referred to the alliance Lolio-Potentillion, a group of natural and anthropogenic vegetation types of unstable lowland habitats, periodically wetted and dried or alternately brackish and fresh.

End group 12

A widespread unit characterized by thick lawns of *Agrostis stolonifera* and *Ranunculus repens* in the virtual absence of sedges. *Polygonum amphibium* is frequent but here without *Glyceria fluitans* or *Ranunculus flammula*. In the patchy taller element *Poa trivialis* is usually the most prominent species though patches of *Phalaris* and *Deschampsia cespitosa* are not infrequent. The sward is species-poor and may be interrupted by bare patches. The vegetation of this End Group is normally mapped as MG13 by botanical surveyoras and there fore this label is given to it here on pragmatic grounds. On phytosociological grounds, this group could be split further into two groups one of which is closer to the OV28 community and the other being an *Agrostis stolonifera*-*Lysimachia nummularia* sward not explicitly recognised by the NVC.

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Appendix I

Synoptic tables for the 12 grassland communities generated by TWINSPAN analysis

	MG5a	MG5*	MG3	MG4	MG4+	MG6b	MG7C#	MG8 Cx	MG8~	Cx dist	Ag/Cx	MG13
Cynosurus cristatus	96	70	99	91	50	64	26	87	69	69	27	5
Festuca rubra	95	99	94	95	61	95	12	76	88	43	3	1
Plantago lanceolata	95	5	100	76	25	66	56	78	54	44	18	3
Lolium perenne	99	36	25	88	72	72	88	37	36	75	29	44
Ranunculus acris	93	78	56	89	84	93	94	93	77	43	34	22
Taraxacum sect. vulgaria	89	14	16	68	52	64	82	58	47	61	35	10
Trifolium repens	89	11	98	76	46	64	75	66	81	90	53	18
Rumex acetosa	84	68	96	82	80	93	90	70	36	15	40	8
Holcus lanatus	76	97	100	88	62	92	37	94	95	74	15	13
Poa trivialis	80	93	90	66	93	35	95	41	59	48	64	85
Anthoxanthum odoratum	69	66	100	75	62	97	91	94	49	28	59	11
Alopecurus pratensis	57	93		55	92	33	86	12	8	2	50	78
Agrostis capillaris	27	51	72	33	15	77	76	36	3		23	2
Cardamine pratensis	6	8	5	14	60	81	72	85	62	95	86	48
Ranunculus repens	44	16	6	15	54	79	97	60	92	100	96	69
Agrostis stolonifera	27	36	27	16	68	28	80	50	82	100	85	93
Calliergon cuspidatum	4	7		5	2	10	17	36	44	44	59	2
Alopecurus geniculatus				1	3	6	19	4	3	2	42	43
Trifolium pratense	89	10	77	78	35	68	33	60	77	30	9	2
Rhinanthus minor	85		73	63	19	3	3	17	8		1	5
Dactylis glomerata	85	45	72	61	11	28	1	1	1		0	0
Prunella vulgaris	70		1	41	7	22	2	34	32	20	3	0
Leucanthemum vulgare	56			48	1	4		1				
Heracleum sphondylium	28	1	4	16	1							
Leontodon saxatilis	20			10		0	1	0			1	
Hordeum secalinum	33	63		34	34	1	2	0			7	21
Luzula campestris	1	64	29	10	4	15		4	2			
Lathyrus pratensis	51	77	26	63	45	12	3	7	19		1	5
Potentilla reptans	19	48	1	19	12	9	1	4		2		6
Primula veris		42		9								
Galium verum		40	3	17	5	0						
Achillea millefolium	1	26	5	7	3	4						
Filipendula vulgaris		37		3	5	0						
Avenula pubescens	5	21	5	9	0	0			1			0
Phleum bertolonii		23		4	1	0						
Trisetum flavescens	49	40	93	53	4	1		1	2		0	
Ranunculus bulbosus	50	49	96	51	6	0	1	0				
Euphrasia confusa			88			1		0	4			
Conopodium majus			55	5	0							
Cerastium fontanum	54	25	99	54	16	80	14	51	68	25	3	3
Trifolium dubium			26	10	8	7	7	17	8		1	2
Bromus hordeaceus hordea	1		31	4	2	16	9	8	3		1	0
Myosotis discolor			37	0	0	14		11	4		1	
Centaurea nigra	73	59	3	81	36	46	32	43	3	11	11	3
Sanguisorba officinalis	20	41	41	68	47	3	4	27	8		1	8
Silaum silaus	44	45		60	33	5	7	1			2	18
Lotus corniculatus	36	29	13	52	21	8		2	3		0	3
Briza media	11	3		24	0	4		3	3			
Brachythecium rutabulum	26	33		33	7	66	48	29	10	2	10	1
Phleum pratense	45	12	1	28	32	53	50	42	7	3	25	14
Poa pratensis	2	4		3	2	22	6	11	6		2	0
Stellaria graminea		4		0	4	52	3	15			0	
Filipendula ulmaria	47		6	51	45	85	27	78	82	8	11	8
Bromus racemosus	51	3		54	31	17	60	17	10	5	13	6
Festuca pratensis	8	8	3	18	27	30	46	33	27	36	19	14
Carex nigra	1		1	5	4	7	22	61	25	46	53	9
Carex panicea	1			2	1	8		55	8	44	3	1

	MG5a	MG5*	MG3	MG4	MG4+	MG6b	MG7C#	MG8 Cx	MG8~	Cx dist	Ag/Cx	MG13
Juncus effusus					2	9	9	39	4	3	19	3
Agrostis canina				1	2	30	20	34	2		10	2
Juncus acutiflorus			2	1	2	2	4	32	8	3	3	2
Carex viridula ssp oedocarp								6				
Carex hirta	17	3	1	8	10	15	1	13	78	16	7	9
Eleocharis palustris					1	1	2	11	64	23	35	9
Caltha palustris			1		3	1	1	26	57	2	15	8
Cirsium palustre					1	6	1	3	36	2	0	1
Lychnis flos-cuculi	1			6	3	5	6	23	36	8	16	
Geum rivale					0				22			
Pulicaria dysenterica					0				27			0
Carex disticha		1		2	11	8	30	43	31	87	40	22
Carex distans					0				3	85		
Senecio aquaticus					7	3	39	24	59	69	55	10
Juncus inflexus					1	4	2	8	15	64	2	3
Juncus articulatus				2	5	4	7	22	49	64	21	3
Bellis perennis	21			16	3	7	11	10	21	57	7	
Eleocharis uniglumis								1	2	48	0	
Festuca arundinacea		22		5	1	2	2	6	5	57	1	2
Juncus subnodulosus					0				2	21	0	0
Trifolium fragiferum										5		
Persicaria amphibia	5			2	12	6	65	13	24	25	82	52
Glyceria fluitans					2	2	13	23	43	21	59	9
Ranunculus flammula					1	0	2	16	2	2	32	4
Oenanthe silaifolia				3	19							21
Phalaris arundinacea					4	0	2	1		2	10	23
Rumex crispus	6			1	9	2	5	1	6	2	7	28
Leontodon autumnalis	57		7	49	40	28	46	45	20	18	38	16
Deschampsia cespitosa ces	6	26	3	12	21	22	23	18	3	10	23	29
Vicia cracca	14	4	11	30	24	21	11	9	8		1	10
Lysimachia nummularia	2	1		1	9	14	3	15	10	38	6	22
Bromus commutatus	27		2	16	23	2	2	21	4		8	1
Arrhenatherum elatius	39	11	1	31	3	9	2	1			0	
Eurhynchium praelongum	23	19		15	4	23	5	4	1		1	0
Leontodon hispidus	12	1	2	20	1	7	1	15	2	18	0	
Cirsium arvense	2	29		5	6	18	9	2	3		0	1
Oenanthe fistulosa					2	0	15	1			36	21
Elytrigia repens		21		1	15	2	2	0			1	19
Galium palustre				0	2	3		26	4	2	11	13
Lotus pedunculatus	4			2	0	16	2	11	19		0	
Carex riparia				0	3	1	10	12	8		11	8
Succisa pratensis	1	14	6	7	2	2		19	2			
Carex acuta				1	12	1		10	3	2	6	12
Potentilla anserina					1	15	1	8	2		14	3
Equisetum palustre	1		1	2	1	1		7	20		1	8
Carex flacca	1	12		11	0	6	1	6	2	2	1	
Myosotis laxa caespitosa					1	2		4	7	2	11	6
Tragopogon pratensis	19			13	0							
Hypochoeris radicata			15	2	1	11		2	1			
Carex acutiformis	1			2	4	0		11	8		0	4
Rumex conglomeratus				0	0				25			4
Veronica serpyllifolia serpyl			1		1	13	3	6	3		1	
Rhynchostegium confertum	7			2	0	15	2	2				
Fritillaria meleagris	10			14	3	0		0				
Ophioglossum vulgatum	11	3		11	1			0	1			
Glyceria maxima					0	0	2	6	3		13	1
Cirsium dissectum				0	1	5		16			1	
Poa humilis					0	15	2	5			0	
Thalictrum flavum	3			2	4	1	2	6			1	3
Medicago lupulina	14			7								
Iris pseudacorus					0			1	18		1	0
Triglochin palustre					0			1	3	13	1	
Epilobium parviflorum									16		0	1

	MG5a	MG5*	MG3	MG4	MG4+	MG6b	MG7C#	MG8 Cx	MG8~	Cx dist	Ag/Cx	MG13
Galium uliginosum					0				14			
Anemone nemorosa			10						1			

Appendix J

Number of samples of each community type found at each site

	Abbreviated site name																	
Twinspan Endgroup	BD	BE	BT	CR	DG	EC	EH	ML	MM	NC	PH	SL	ST	TA	UH	UW	WM	WS
1										1			107					
2	50		14	437	5	18			8		141				5	80		
3				112						3						1		
4	17		130	181	26	85	8	25	12		71	1		22	131	15		3
5			24								1			1		47		
6	3			13	3	4	1		2	35		2	4	427		5	1	
7	9		1		2			1		2		91		19		1		1
8		2		1			81	7	3	17			6	1				
9				6				65	190			5	1	300				54
10								59									1	
11	4	1	1	7	6			35		1	1	73		43		4	169	2
12	6	9	28	64	3	23					16	3		2	64	11	4	
13		20												2				
14		37																

Abbreviation	Site Name
BD	Broad Dale
BE	Belaugh
BT	Blackthorn
CR	Cricklade
DG	Dancing Gate
EC	East Cottingwith
EH	East Harnham
ML	Moorlinch
MM	Mottey Meadows
NC	Nethercote
PH	Portholme
SL	Southlake
ST	Stonygillfoot
TA	Tadham
UH	Upton Ham
UW	Upwood
WM	Wet Moor
WS	West Sedgemoor

Appendix K

Favoured water regimes of grassland plant communities

This appendix presents nine plots covering all the plant communities studied in this project. The format of the plots is as described in the introduction to Appendix E. *It is the area of dark tone that is said to reflect the "favoured" water regime of the species*.

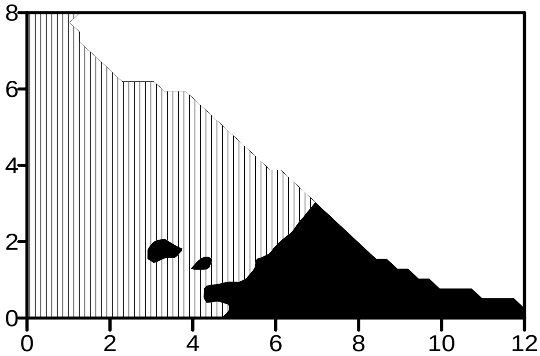
On all plots the horizontal axis reflects the degree of soil drying (SEV_d/metre.weeks) and the vertical axis reflects the degree of waterlogging (SEV_a/metre.weeks)

The communities are depicted in the following order (some botanically similar communities that have considerable overlap in their water-regime tolerances have been combined for clarity):

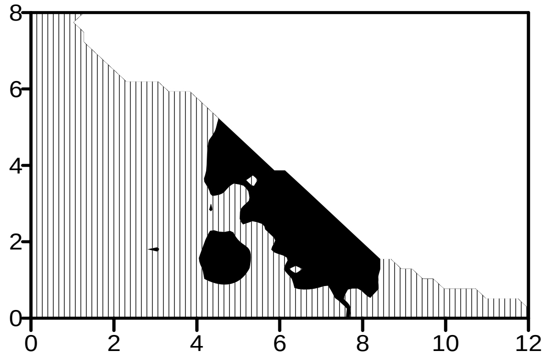
End Group	**NVC code**	**Community name**	**Vegetation type**
2	MG4	*Alopecurus pratensis-Sanguisorba officinalis* grassland	Floodplain meadow
4	MG4+	*Alopecurus pratensis-Sanguisorba officinalis* grassland, species-poor variant	Floodplain meadow
3	MG5a	*Centaurea nigra- Cynosurus cristatus* grassland *Lathyrus pratensis* sub-community	Old hay meadow
7	MG7C#	*Lolium perenne-Alopecurus pratensis-Festuca pratensis* grassland, species-rich variant	Flood pasture
8	MG8	*Cynosurus cristatus-Caltha palustris* grassland	Water meadow
12	MG13	*Agrostis stoloniofera-Alopecurus geniculatus* grassland *Alopecurus pratensis* variant	Inundation grassland
10,11	*Ag/Cx*	*Agrostis/Carex* grassland (both variants)	Water meadow
1	MG3	*Anthoxanthum odoratum-Geranium sylvaticum* grassland	Upland hay meadow
13,14	S24, S25	*Phragmites australis-Peucedanum palustre* tall-herb fen/ *Phragmites australis-Eupatorium cannabium* tall-herb fen	Rich fen

Non-technical summary of community tolerances:

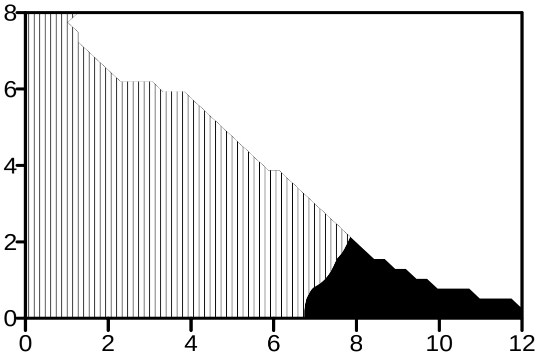
MG4	Tolerates a wide range of soil drying, provided waterlogging is avoided.
MG4+	Differs from MG4 proper in being more tolerant of both waterlogging and water table fluctuation, but less often found on soils that dry considerably.
MG5a	Tolerates soils that dry considerably, but not those which experience waterlogging.
MG7C#	Most frequent in mid range of both soil drying and waterlogging. Water tables fluctuate considerably through the growing season.
MG8	Tolerant of a range of waterlogging regimes, but intolerant of soil drying. Water tables fluctuate relatively little over the growing season.
MG13	Requires considerable waterlogging in the growing season, but not permanent waterlogging. Tolerates a wide range of soil drying situations.
Ag/Cx	Similar to the MG13 *Alopecurus pratensis* variant above, but even more tolerant of waterlogging in the growing season.
MG3	Intolerant of waterlogging, but tolerant of soil drying (similar to MG5a)
S24, S25	Requires waterlogged soils almost throughout the growing season. Intolerant of any appreciable soil drying



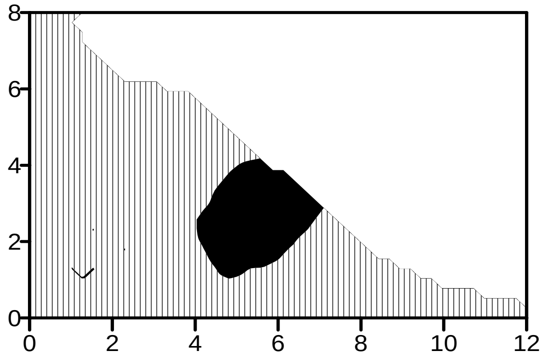
MG4 community



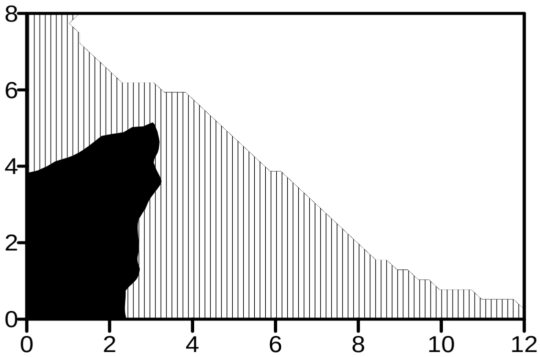
MG4 community species-poor variant



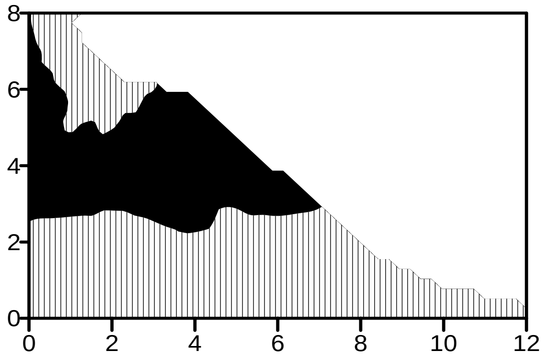
MG5a sub-community



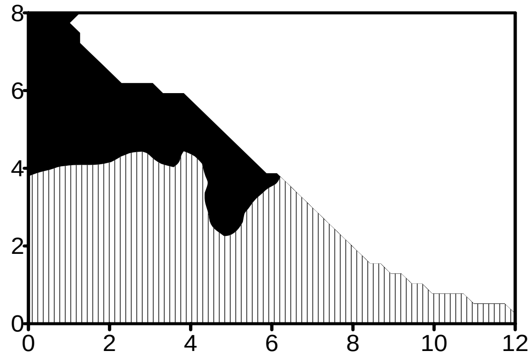
MG7C community species-rich variant



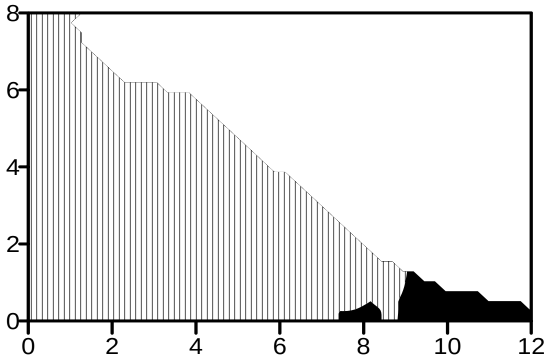
MG8 community



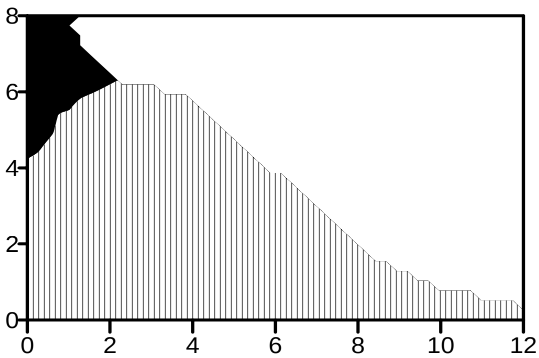
MG13 community, Alopecurus pratensis variant



Agrostis-Carex community



MG3 community



S24/S25 communities

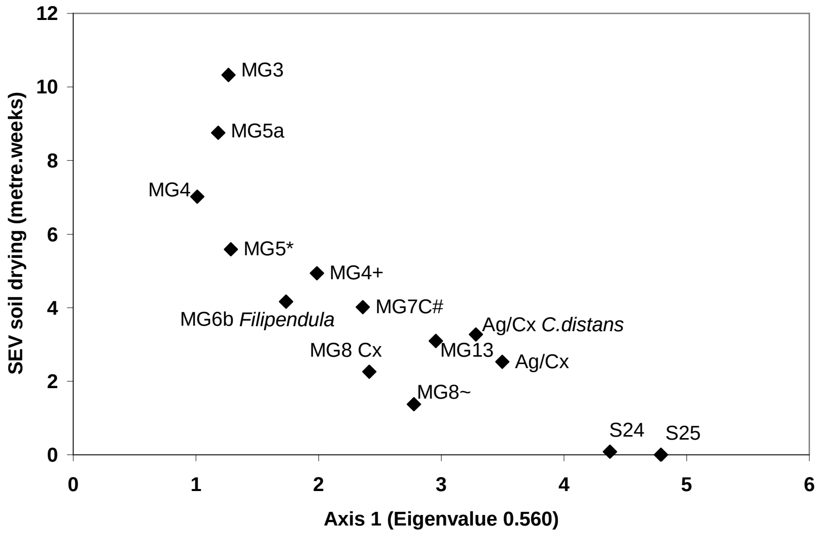


Figure L3. Plot as for L2 above but using SEV(soil drying) instad of waterlogging. The relationship here is less strong, but still apparent.

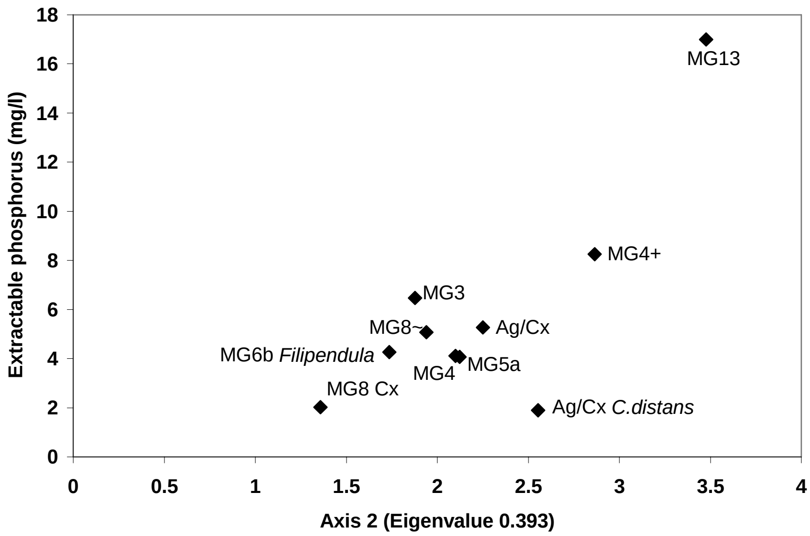


Figure L4. A plot of the mean phosphorus availability for each of the community types plotted against the second axis of variation of the DCA ordination. The weak correlation between the two variables suggests phosphorus availability may be one of the factors determining botanical composition as described by axis 2, but other factors are also likely to be important**.**

Appendix M: Cricklade Synoptic table

Twinspan group	1	2	3	5	4	6	7	8	9	10	11	12	13
Species													
Alopecurus pratensis	80	93	100	99	99	100	98	70	66	13			
Trifolium repens	88	90	84	91	94	90	84	61	49		9		
Lolium perenne	100	90	95	99	100	99	80	30	15	3		4	
Ranunculus acris	96	99	95	96	94	87	38		3				
Rumex acetosa	80	94	89	91	86	92	68	22	6				
Plantago lanceolata	100	97	100	96	81	70	48	35	1				
Taraxacum sect. vulgaria	100	99	100	94	93	95	80	30	10				
Bromus racemosus	96	94	89	89	99	62	29						
Festuca rubra	100	99	95	91	89	48	11						
Trifolium pratense	92	99	84	93	74	55	14		1				
Cynosurus cristatus	96	100	95	76	99	28	9						
Anthoxanthum odoratum	96	100	89	69	79	13	7						
Holcus lanatus	96	94	74	52	95	13	3						
Filipendula ulmaria	92	83	84	78	48	55	55	43	6		12		
Centaurea nigra	92	92	79	94	42	66	62	26	3				
Lotus corniculatus	68	65	89	68	12	41	34	17	6				
Ranunculus bulbosus	72	43	26	31	67	7							
Prunella vulgaris	88	74	58	54	28	18	3						
Leontodon hispidus	76	70	79	28	7	3							
Rhinanthus minor	52	58	5	32	44	5	1						
Leucanthemum vulgare	96	69	47	24	26	1							
Dactylis glomerata	84	11		14	70	8							
Trisetum flavescens	84	28	5	8	44	1							
Bellis perennis	52	19	26	24	5	2	2						
Avenula pubescens	28	1		1	2								
Ophioglossum vulgatum	20	10	5	8		3	1		1				
Heracleum sphondylium	16				9								
Arrhenatherum elatius	16			2	9	1							
Sanguisorba officinalis	20	80	100	47	74	32	8	4					
Silaum silaus	84	100	100	91	32	52	83	91	53	10	24		
Leontodon autumnalis	72	99	100	93	51	71	75	57	24	3	3		
Cerastium fontanum	32	79	53	14	23		1						
Carex flacca	24	45	26	15		1							
Briza media	20	31	26	4	4								
Fritillaria meleagris		13	5	9	1	7	6		1				
Luzula campestris		17	5	2									
Cardamine pratensis	4	61	100	61	19	60	76	91	43	10	41		
Carex panicea	4	13	89	8		3	8						
Lychnis flos-cuculi		36	68	17	1	3	3						
Deschampsia cespitosa cespitosa	12	33	63	25	4	15	21	4	15	3			
Calliergon cuspidatum		15	47	6		7	7	4					
Agrostis capillaris		4	16	6		1							
Succisa pratensis		3	16										
Lathyrus pratensis	40	36	16	49	77	48	28	17	4				
Hordeum secalinum	60	8		43	73	69	35	13	7				
Agrostis stolonifera	20	40	68	43	16	48	93	96	96	93	97	91	83
Lysimachia nummularia			5	6		12	54	87	71	43	79	9	
Oenanthe fistulosa		1		3		1	12	35	54	23	56	48	33
Carex nigra		9	16	2		3	24	43	40	20	12	4	
Carex disticha		1		4		5	33	87	41	17	74	4	50
Phleum pratense		24	26	35	10	37	31	57	4	7		4	
Ranunculus flammula		2	16	12		29	31	43	9	23	18	4	
Trifolium fragiferum						1	6	39	6		12		
Carex hirta	12	3		14	2	18	32	43	28	3	3	4	
Alopecurus geniculatus						1	5	4	43	17	15	4	
Caltha palustris							1		13	7	6	4	
Filipendula vulgaris				1	2	1	1	4	6	20		9	
Potentilla anserina							2	9	3	23		4	
Juncus articulatus		1				1	1	9	6	20	3		
Rumex crispus				1	4	9	31	61	68	97	94	35	50
Carex acuta	4			6		6	10	43	28	47	94	17	17
Equisetum palustre				1		3	9	17	26		44	4	
Phalaris arundinacea							1		10	10	9	65	
Persicaria amphibia	16	1		11	9	20	22	17	57	97	79	100	100
Eleocharis palustris							1	4	13	7	6	4	100
Glyceria fluitans					1				1			26	50
Galium palustre							5	22	24	50	21	30	67
Poa trivialis	72	52	95	97	95	97	92	26	85	17	26		
Ranunculus repens	16	20	32	40	28	55	56		49	20	12	22	17
Festuca pratensis	28	6	32	26	11	27	22	30	12				
Vicia cracca	4	9	11	23	14	21	24	13	13		6		
Myosotis laxa caespitosa							5	13	7	7	3		
Potentilla reptans	8	8		6	1	5	8	13	4				
Brachythecium rutabulum	8	11		3	1	1	1						

Notes on change End Groups at Cricklade

EG1. (MG5)

Referable to 3904 EG3 but the Cricklade samples are more species-rich with higher frequencies of *Lolium, Leontodon hispidus, Leucanthemum, Trisetum, Hordeum secalinum* and *Filipendula ulmaria* but less *Rhinanthus*. Present in 14 quadrats in 1998, the nodum has declined steadily and was not represented in 2001. The progression was almost invariably to endgroup 6, Species-poor MG4.

EG2. (MG4)

Referable to 3904 EG2 but these are again more species-rich and rather closer to the typical NVC MG4. *Silaum, Filipendula, Cardamine pratensis, Loentodon spp.* and *Bromus racemosus* are all enhanced and the higher frequencies of *Briza* and *Carex flacca* add a local flavour. Initially present in a similar number of quadrats as EG1, EG2 was more stable and some loci have persisted – the others moving to EG6 but more slowly than have the samples of EG1.

EG3 (MG4).

Another part of the 3904 EG2 envelop but perhaps rather closer to its 'centre of gravity': *Silaum, Filipendula, Leontodon autumnalis* and *Bromus racemosus* remain highly inflated but other species less so. Has displayed a steady decline to extinction by 2001; most of the loci have shifted to EG7 often *via* EG6 thus showing a shift from MG4 'typical' through MG4 species-poor to MG7C.

EG4 (MG4 species-poor variant).

Part of the poor MG4 of 3904 analysis. Many of the characteristic species are here present at reduced frequencies. Thus there is less *Silaum, Filipendula, Centaurea nigra, Prunella* and *Leontodon autumnalis* whilst *Sanguisorba* is more patchy; only *Hordeum secalinum* has an increased constancy. One of the more prevalent units in 1998, though largely confined to the control area, the group reached a peak in 2000 at the expense of the 'drier' MG5, before crashing in 2001 when the majority of samples had transferred to EG6, also the present location of many examples of EG3.

EG5 (MG4 species-poor variant)

Also part of the species-poor MG4 of 3904 analysis. The most frequently identified group over the four years EG6 differs structurally from EG4 in the much better representation of lower story species. Though *Sanguisorba, Dactylis* and *Hordeum secalinum* are less prevalent, a suite a lower-growing species including *Lotus corniculatus, Cardamine pratensis, Leontodon spp., Carex flacca* and *Agrostis stolonifera* all display higher frequencies.*Silaum* is also better represented. EG6 is clearly a pivotal stage in the recent progression on Cricklade: it has largely been derived from 'typical' MG4 of 3904 EG2 and in turn progresses in most cases to the form of MG7C represented by EG6 on Cricklade.

EG6 (MG7C species-rich variant)

Broadly similar to 3904 EG7, MG7C, but differing from that unit, which was not represented from Cricklade in the main Twinspan, in the presence of both *Silaum* and *Sanguisorba* at constancy IV and III respectively. The general floristics indicate a transition between species-poor MG4 and MG7C proper. The endgroup has increased steadily in frequency and by 2001 was the commonest vegetation type amongst the Cricklade samples. The great majority of the present examples have been derived from the species-poor MG4 of EG5 whilst where EG6 samples have themselves changed the progression is usually to the wetter EG8.

EG7 (*MG13*)

EG9 marks the point in the progression from dry grassland to inundation communities where *Agrostis stolonifera* becomes constant and *Lysimachia nummularia* characteristic. The unit has steadily increased on the site, being derived from the MG7C of EG6 in the control area and from species-poor MG4 of EG5 over the rest of the monitoring area. Though EG7 was present at 20 stations in 2001, at other locations eg between quadrats 55 and 87 it has been succeeded by vegetation possibly referable to the *Agrostis stolonifera-Ranunculus repens* community and locally expressed as EG9.

EG8 (OV28)

The unit is broadly similar to EG7 but is an even lower growing and more species-poor sward. It lacks the moderate to high frequencies of *Filipendula, Deschampsia cespitosa* and *Plantago lanceolata* and also the cover of *Carex disticha* and *C.nigra* which is characteristic of EG7. *Rumex crispus* and *Polygonum amphibium* are more prevalent with the high frequency of *Lysimachia* being maintained. EG8 appears very unstable: although the number of occurrences in 1998 and 2001 are the same at only a solitary locus has the unit been constantly present. At all others it forms part of a succession. In most instances EG8 has been derived from EG6, a progression from MG7C to OV28 vegetation. However its destination differs somewhat across the site; over the first 55 quadrats the trend is EG8 to EG9 whilst beyond that point the change is from EG8 to EG10.

EG9 (*OV28*)

EG9 retains more of the damp rather than wet meadow species than does EG10 and *Filipendula* remains moderately frequent; the samples are particularly characterized by having *Carex disticha* as a constant. The endgroup was restricted to two loci in 1998 but had shown a rapid expansion in 2001. It has been derived in two ways: most of the samples have shifted from endgroups 7 and 8 with a marked decline in species diversity; others appear to oscillate between EG9 and EG10 but with a recent tendency to fall into EG9.

EG10 (*Agrostis-Carex)*

EG10 closely resembles EG9. It is chiefly distinguished by the much enhanced frequencies of *Alopecurus geniculatus* and *Polygonum amphibium* and corresponding declines in *Carex disticha, Silaum* and *Filipendula.* It is more of an *Agrostis* lawn with clumps of *Alopecurus pratensis* rather than a layered vegetation. Initially prevalent, EG10 has declined. It appears to interact with EG9 as a pair of 'accordion' units, each seemingly expanding and contracting at the expense of the other. Elsewhere, and rather more frequently, EG10 is transformed to the vegetation of EG11, *Agrostis stolonifera-Carex acuta* stands lacking *Alopecurus pratensis*.

EG11 (*Agrostis-Carex*)

The first of a group of species-poor swards, EG13 has constant *Polygonum amphibium* and *Rumex crispus,* frequent *Galium palustre* and retains *Lysimachia*. It also retains constant *Agrostis stolonifera* and some *Alopecurus pratensis* but is otherwise grass-poor. It seems not to be represented in the 3904 Twinspan. The samples are concentrated between quadrats 22 and 43, plus a few outliers, and their frequency has shown only a modest increase over time.

The additions have been at the expense of EG12 through species loss and colonization by *Rumex crispus* and *Polygonum amphibium*. In other instances EG13 is linked with EG15 in a similar oscillating patterns to that seen with EG11 and 12. In this case the shift seems to be driven by annual fluctuations in patch size and hence frequency in quadrats of *Carex spp.* and *Alopecurus geniculatus*.

EG12 (A10)

Very species-poor vegetation with only *A.stolonifera, Polygonum amphibium* and *Phlaris* achieving more than 50% frequency. The unit is referable to a terrestrial form of A10, the *Polygonum amphibium* community. EG12 appears stable at some locations around the old stream course whilst at others it alternates over time with EG11.

EG13 (S19).

A form of S19c, the *Agrostis stolonifera* sub-community of *Eleocharis palustris* swamp seemingly occupying the areas having the longest duration of inundation. It has occupied the locus of Q21 throughout the monitoring period and has recently replaced EG11 in and around Q25.

Appendix N: West Sedgemoor Synoptic table

Community	MG8	MG8	Transition MG8/ Ag-Cx		Ag-Cx	Ag-Cx	Ag-Cx	Ag-Cx	OV28
Twinspan group	1	2	3	4	5	6	7	8	9
Species									
Cynosurus cristatus	100	100	88	98	80	25	79	21	42
Anthoxanthum odoratum	100	100	93	98	83	44	84	41	52
Filipendula ulmaria	85	91	96	83	87	65	79	21	65
Cardamine pratensis	90	94	96	96	97	96	89	97	58
Senecio aquaticus	90	94	88	83	77	92	32	65	26
Holcus lanatus	98	97	77	92	73	15	74	12	55
Plantago lanceolata	88	94	94	87	50	52	16	9	23
Cirsium dissectum	73	91	74	89	40	54	21	18	6
Carex panicea	75	81	80	100	70	60	74	44	
Ranunculus acris	90	88	77	74	47	35	37	9	35
Agrostis canina	93	100	58	40	40	27	21	9	
Centaurea nigra	83	78	61	62		8	5		6
Leontodon hispidus	68	69	39	51	7	6			
Trifolium pratense	48	47	41	43	10	2	5		
Polygonum persicaria	33	31	1	2		2			
Bromus commutatus	90	59	35	34	7	10			6
Vicia cracca	38	6	6	17	3	2	5	3	
Caltha palustris	33	88	83	34	87	77	53	62	39
Lychnis flos-cuculi	8	53	20	19	7	2		3	
Hydrocotyle vulgaris	3	34	19	11	20	19		21	
Juncus conglomeratus	13	22	13	8	7	4	5	3	3
Rhinanthus minor	3	6	22	8	13				3
Leontodon autumnalis	50	53	70	43	63	58		3	23
Rumex acetosa	28	34	45	17	13	13			13
Prunella vulgaris	35	22	19	43	10				6
Trifolium repens	50	56	65	77	67	56	63	32	10
Agrostis stolonifera	50	31	96	94	97	100	100	100	100
Ranunculus repens	58	81	84	66	87	96	79	85	100
Poa trivialis	60	34	71	64	97	87	95	97	94
Ranunculus flammula	60	84	78	92	83	98	89	100	48
Carex nigra	63	78	84	91	97	94	95	94	19
Myosotis laxa caespitosa	5	31	57	42	77	65	47	68	26
Phleum pratense	43	28	49	30	20	65	58	47	42
Calliergon cuspidatum		9	48	92	63	71	100	94	6
Juncus effusus	58	13	22	64	30	29	84	65	35
Persicaria amphibia	5	19	51	74	63	79	68	91	52
Galium palustre	28	31	41	49	37	35	63	76	19
Eleocharis palustris		3	6	2	17	19	32	74	19
Juncus articulatus	10	3	7	17	43	27	58	62	23
Phalaris arundinacea		6		9		12	16	47	16
Mentha aquatica		3				4		12	
Glyceria fluitans	5	3	14	9	37	37	16	68	74
Carex riparia	8	9	12	2	10				39
Alopecurus geniculatus	3		1		3	4		3	32
Festuca pratensis	70	53	62	45	50	75	53	44	39
Thalictrum flavum	78	47	38	77	27	56	84	53	3
Triglochin palustre		6	29	26	23	58	37	56	10
Lolium perenne	23	3	14	9	3	2	5		32
Taraxacum sect. vulgaria	18	13	28	17	10	2	11		13
Deschampsia cespitosa		6	10	8	7	15			10
Bromus racemosus			12	8	10		16	3	3
Carex demissa		9	9	9	7	2	11		
Festuca arundinacea		6	3	2	10	6		6	
Brachythecium rutabulum	10		1	4					

West Sedgemoor change noda

Position in relation to the full 3904 TWINSPAN analysis.

In 1993 most of the samples in both fields were placed in the MG8 type of EG9, they rapidly shifted to a transitional phase between EG9 and the *Agrostis-Carex* unit and then into *Agrostis-Carex* proper (EG11). Some stands finally were placed in the *Agrostis-Ranunculus* unit (EG12).

EG1, MG8

The principal vegetation unit in field 1401 in 1993; a tall, grass-dominated, sward cut for hay and aftermath grazed. The principal grasses were *Cynosurus, Anthoxanthum* and *Holcus lanatus* with bulky forbs including *Centaurea nigra, Filipendula* and *Plantago lanceolata*. Distinguished from field 1412 by the prevalence of *Bromus commutatus, Festuca pratensis* and *Thalictrum flavum*. A rich understory of herbs was present including *Carex panicea, Prunella, Trifolium pratense* and *Leontodon hispidus.*

EG2. MG8.

Similar to EG1 in being a tall, bulky, grass-dominated sward but distinguished by the greater prevalence in the centre of the field of lower growing species; *Caltha palustris, Cirsium dissectum, Ranunculus flammula, Myosotis laxa* and *Lychnis flos-cuculi.* This was the principal vegetation type in field 1412 in 1993.

EG3. MG8/*Agrostis-Carex* transitional vegetation

Mainly derived from EG2 in field 1412 where it remained the principal vegetation during 1994 and 1995. The frequency and cover of the principal grasses (*Holcus, Cynosurus* and *Anthoxanthum*) was significantly reduced producing a more open, low-growing sward in which *Agrostis stolonifera* provided the bulk of the grass cover. Many of the characteristic MG8 herbs including *Caltha, Carex panicea, Leontodon hispidus* and *Cirsium dissectum* declined whilst marked increases were noted for *Myosotis laxa, Polygonum amphibium* and *Triglochin palustre.*

EG4. MG8/*Agrostis-Carex* transitional vegetation

The unit represents a parallel change in field 1401 to that observed in 1412. EG4 is largely derived from EG1 with reductions in the principal grass species, including losses of *Bromus commutatus*, *Anthoxanthum* and *Festuca pratensis*. Here however, the increase in *Agrostis stolonifera* was accompanied by increases in *Carex nigra* and *C.panicea*. Few other changes were observed.

EG5. *Agrostis-Carex*

A transient vegetation unit in field 1412 where it was prominent between 1998 and 2000. *Agrostis stolonifera* and *Poa trivialis* now provide the bulk of the grass cover with increases in *Juncus effusus, J.articulatus, Polygonum amphibium* and *Myosotis laxa.* Most other species were either static or showed modest declines. The greatest declines being amongst the 'drier' species, *Trifolium pratense, Centaurea nigra* and *Leontodon hispidus*.

EG6. *Agrostis-Carex.*

A transient unit in field 1401 in 1995 but the principal endpoint vegetation in field 1412 by 2001. *Agrostis stolonifera* and *Carex nigra* co-dominate the sward providing a mosaic of low-growing mats and taller sedge lawns with patches of *Cirsium dissectum, Senecio aquaticus* and *Caltha; Ranunculus repens* is more prevalent. *Triglochin palustris* reaches its maximum frequency here together with *Phleum pratense* and *Festuca pratensis*. Similar declines in the drier elements of the vegetation are observed.

EG7. *Agrostis-Carex.*

A transient unit in field 1401 in 2000. The loss of the drier elements of the flora is now more or less complete with the disappearance of *Leontodon hispidus, Lychnis flos-cuculi, Bromus commutatus, Rumex acetosa, Rhinanthus minor* whilst rushes (*Juncus effusus* and *J. articulatus*) achieve their highest frequency and cover here. *Carex nigra* lawns are prominent and exceed *Agrostis stolonifera* in overall cover producing a patchwork of low species-rich lawns supporting *Triglochin, Myosotis laxa, Polygonum amphibium* interspersed with taller rush-dominated patches with *Galium palustre*.

EG8. *Agrostis-Carex*.

This is the main endpoint for field 1401 with many sample loci being stable in this group since 1998. Characterised by low swards of *Carex nigra, Agrostis stolonifera, Glyceria fluitans, Eleocharis palustris* with *Juncus articulatus* and *Triglochin palustris* also distinctive features and with *Polygonum amphibium* at its most abundant here.

EG9 OV28.

A relatively small group of samples in which *Agrostis stolonifera*, *Ranunculus repens* and *Glyceria fluitans* provide a low carpet in the more or less complete absence of low growing sedges. *Carex riparia* provides the structural element in EG10 whilst *J.effusus* is prominent in EG9. Recorded early on in field 1401 suggesting the presence of some low-lying lenses within the field.

AppenbdixO: Tadham Synoptic table

Community	MG6F	MG6F	MG6F	MG6F	MG6-AC	MG6-AC	Ag-Cx	Ag-Cx	Ag-Cx	OV28	S19	MG13
Twinspan group	1	2	3	4	5	6	7	8	9	10	11	12
Species												
Anthoxanthum odoratum	100	99	100	99	99	88	98	54	12	41		
Holcus lanatus	96	93	100	97	99	100	94	48	1	76		
Rumex acetosa	85	98	97	96	88	85	92	51	12	59	6	
Ranunculus acris	93	96	97	97	91	92	91	52	7	35	6	
Cardamine pratensis	90	84	95	92	90	92	94	79	72	35	28	33
Plantago lanceolata	90	73	94	82	87	65	97	60	15	35		
Festuca rubra	99	98	85	87	74	58	67	9	1	12		11
Filipendula ulmaria	99	95	100	91	93	38	81	72	37	18	17	11
Agrostis capillaris	95	82	77	61	31	35	44	20	9	12		
Centaurea nigra	84	64	73	64	32	12	13	2	1			
Brachythecium rutabulum	78	57	44	49	27	12	43	18	15	6		33
Cerastium fontanum	70	46	61	65	41	50	37	2		6		
Stellaria graminea	67	59	45	45	15	8	21	6	3		6	
Luzula campestris	71	14	50	10	4							
Vicia cracca	30	18	23	20	9	4	3	2				
Hypochoeris radicata	44	6	27	4	5		1	1				
Lotus corniculatus	27	18	11	13	8		6					
Carex flacca	38	4	29	4	7							
Eurhynchium praelongum	62	35	13	19	6		11	4	3	6		
Cirsium dissectum	21	6	10	7	5		1					
Briza media	23	2	15	1								
Leucanthemum vulgare	15	8	6	2	1							
Dactylis glomerata	29	47	5	8	1	8	4	1				
Cirsium arvense	3	15	2	8								
Cynosurus cristatus	71	49	87	76	77	46	51	7	1	18		
Festuca pratensis	36	29	50	35	43	27	40	17		6		
Deschampsia cespitosa c	25	41	48	20	16		10	2				
Prunella vulgaris	33	11	53	16	23		13	5				
Juncus acutiflorus	15	2	24	10	22		9	15	6			
Myosotis discolor	5	12	18	16	11	4	5					
Ajuga reptans	11	8	23	2	1		1	1				
Juncus conglomeratus	4	1	10	2	2		1	2				
Lolium perenne	47	52	79	89	70	77	42	15	1	18	6	
Trifolium pratense	67	39	63	68	44	12	27	5				
Carex hirta	5	10	13	44	31	4	16	10	3		6	
Bromus hordeaceus hord	18	21	19	31	26	27	8			6	6	
Bromus racemosus	26	12	61	64	68	46	46	18	1	29		
Trifolium repens	40	15	44	45	55	19	39	13	3	12		
Lychnis flos-cuculi				3	18	4	6	11	6		6	
Poa trivialis	7	27	45	66	76	96	31	26	9	59	6	
Geranium dissectum		5		3		15						
Potentilla reptans	8	17	2	13	1	19		2				
Agrostis stolonifera	30	72	61	85	86	88	91	100	99	88	100	78
Ranunculus repens	42	54	89	90	96	96	88	85	64	82	50	56
Carex disticha	3	8	8	35	80	65	91	90	94	41	72	78
Carex nigra	15	11	15	8	37	4	87	78	93		6	
Phleum pratense subsp.p	56	51	53	69	68	65	77	73	7	29	6	
Leontodon autumnalis	7	3	6	8	19	8	31	13	6			
Juncus articulatus	8	2	11	5	20	12	19	37	7		17	
Juncus effusus	1	7	37	22	59	12	37	62	51	18	22	33
Caltha palustris		1			4	4	7	16	51	12	17	22
Myosotis laxa caespitosa		1			4		4	24	45		33	
Galium palustre		7	13	4	12	4	32	54	76	6	56	
Lysimachia nummularia	12	10	15	15	24	15	10	16	33	6	6	11
Hydrocotyle vulgaris								4	16		6	
Rumex crispus			3	3	3	23	4	6	1	65	17	11
Alopecurus geniculatus			2		1	15	5	2	6	41	11	11
Epilobium hirsutum		1			1					12		
Eleocharis palustris		2		1	7	4	20	51	36	12	61	22
Carex riparia	3	3	2	3	24	77	7	9	31	76	94	22
Drepanocladus aduncus							5	5	21		39	11
Ranunculus flammula		1			1		2	2	19		33	
Stellaria palustris					2		4	9	9		17	
Carex rostrata					1				3		33	
Oenanthe fistulosa							2		16		17	11
Iris pseudacorus					4		1	6	3		17	
Rumex hydrolapathum							1	1			17	11
Persicaria amphibia	3	3		8	29	38	37	49	51	35	56	56
Juncus inflexus		2	5	8	7		8	18	6		22	22
Lemna minor								1	3		11	11
Glyceria maxima		1		1	1	8	14	18	61	76	94	100
Glyceria fluitans	1	2	2	8	31	54	41	61	55	53	78	100
Filamentous algae					1			1	6	6	6	33
Myosotis scorpioides												11
Taraxacum sect. vulgaria	71	56	71	76	84	85	86	49	12	29	6	

AppenbdixO: Tadham Synoptic table

Calliergon cuspidatum	14	13	52	32	81	19	69	78	69	6	33
Alopecurus pratensis	32	46	27	52	38	54	20	6	4	35	
Carex panicea	38	6	29	4	11		20	17	19	6	6
Potentilla anserina	4	18		14	7	8	9	4	4		6
Poa pratensis	4	11	10	15	4	12	9	1	1		
Elymus repens (syn)	4	7		3	1		2				
Lathyrus pratensis	7	14	13	15	6		3	1			
Poa subcaerulea (syn)	3	13	11	13	4	4	3	1			
Rhinanthus minor	8	1	5	10	12		5	2			
Lotus uliginosus (syn)	12	5	8	6	7		2		1		
Equisetum fluviatile		2	5	4	12		9	1	3		
Agrostis canina	4	7	3	7	1	4	5	2	3		
Trifolium dubium		2	8	4	7	8				6	
Triglochin palustre				1	1	4	5	10	6		

Tadham change twinspan

The basic problem with interpreting the Tadham data seems to be that so many of the quadrats represent one general vegetation type present in a variety of local forms. This basic type was, at the outset, somewhat intermediate between damp expressions of MG5 and MG6 and forms the nucleus of the 3904 Twinspan endgroup 6 provisionally described as the *Filipendula* variant of MG6b.

There appears to have been a shift over time from this vegetation into a sward transitional between MG6 *Filipendula* and a form of the *Agrostis-Carex* community and thence, often, to *Agrostis-Carex* proper. There is however no one simple gradient since in 1994 all three main types were already present and the degree of movement along the gradient of increased flood tolerance varies considerably.

The areas already supporting the structurally complex patchwork of the *Agrostis-Carex* community have remained relatively stable. Those, typified by endgroup 7, of which a few started as the MG6/*Agrostis-Carex* transitional unit have tended to loose the basic *Lolium-Cynosurus* elements, have become more species-poor, and have changed into the *Agrostis-Carex* community.

The majority of the samples, those initially located within the MG6 *Filipendula* envelop, can be partitioned into three groups. The 'driest', endgroups 2 and 3 were initially stable but by 1998 had come to support high cover of *Agrostis stolonifera* and transferred to an even damper form of the same unit typified by endgroup 5. Others had become increasingly rush-invaded to produce a new variant of the MG6 unit represented by endgroup 4. The remainder had lost much of the formerly prevalent grass combination of *Lolium, Cynosurus, Festuca rubra* and *Agrostis capillaris* and with the introduction of *Persicaria amphibia*, *Calliergon* and, patchily, *Carex nigra* had moved out of the MG6 envelop and become transitional MG6/*Agrostis-Carex* stands.

The *Agrostis stolonifera*-rich sward of endgroup 5 seems to be an ephemeral vegetation. Derived from the drier end of the MG6 *Filipendula* envelop, many of its component samples have over time become converted to examples of endgroup 7 vegetation and thus have moved from MG6 to the MG6/*Agrostis-Carex* transition.

Thus, the dominant shift appears to be

MG6 *Filipendula*		MG6 *Filipendula Agrostis*		MG6/Ag-Cx Transition		Ag-Cx
EG 2/3	→	EG 5	→	EG 7	→	EG11/12

with a 'branch-line' where members of endgroups 2 and 3 have lost much of their *Alopecurus pratensis* but display enhanced frequencies of *Juncus effusus, Festuca pratensis* and *Calliergon* and have shifted only slightly along the moisture gradient to form the new endgroup 4 still within the MG6 *Filipendula* envelop.

Endgroups 6 and 8 are less frequent versions of 7 which have arisen where *Carex riparia* has invaded vegetation progressing from MG6 to the MG6/*Agrostis-Carex* transition. Endgroups 9 and 10 contain samples which were already in transition at the start of monitoring and which have tended to shift to *Agrostis-Carex* proper: EG9 to EG12 and EG10 to EG11. Finally, endgroups 13 and 14 seem to represent the more *Carex disticha* and *Caltha*-rich stands of *Agrostis-Carex* which are expanding only slowly.

A feature of the changes is the apparent lack of any examples of samples moving from a ‘wetter’ to ‘drier’ position on the gradient; so the site still appears to be getting wetter.