Regional stability versus fine scale changes in community composition of mesotrophic grasslands over 25 years.

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Abstract

Long-term studies of vegetation change in grasslands are important to our understanding of the ecology and management of grassland systems, especially for grasslands of high conservation value which have seen a drastic decline due to agricultural intensification and abandonment. This study investigated change over 25 years in 35 mesotrophic grassland sites which were described as species rich at the start of the study period. Some sites had been consistently managed by mowing or grazing whilst others had seen a change to more intensive management or to little or no regular management. Baseline data were available for both quadrat and species list surveys and repeat surveys were undertaken using the same methods on all 35 sites. Multivariate analysis using non metric multidimensional scaling revealed that the overall community composition was similar in the original and repeat surveys but some differences were revealed when the sites were categorised by management type. The two survey methods provided different information about both the principal vegetation communities and about other aspects of the site including the presence of rare species. There were losses and gains of species of importance to conservation with more losses than gains overall and there was some evidence for species losses at sites which had been managed consistently for conservation. These changes may be linked to aspects of the management regime, isolation of sites or changes in soil fertility levels but a greater understanding of the local and regional processes affecting diversity in mesotrophic grasslands is required to inform conservation management.

Keywords

Long-term change; semi-natural grasslands; conservation; community composition; species loss; scale

Introduction

Species-rich grasslands support a rich diversity of vegetation but they are particularly vulnerable to change (Habel *et al*., 2013). In Europe the maintenance of diversity in such grasslands usually requires an extensive agricultural management regime (Wesche *et al.*, 2012), so the widespread adoption of intensive agricultural practices and the abandonment of more inaccessible or unproductive grasslands has resulted in the loss of the majority of species rich grasslands in most European countries (Stoate *et al*., 2009). Studies which record long-term change in the remaining species rich grasslands are rare but can make a valuable contribution to our understanding of ecological processes as well as helping to inform management approaches (Magurran, *et al.*, 2010; Silvertown *et al.*, 2010).

Some of the most diverse vegetation communities are found in calcareous grasslands and these habitats have been the subject of studies concerning change resulting from various influences and at different scales (Bennie *et al.*, 2006; Diekmann *et al.*, 2014; Van den Berg *et al.*, 2011). Although some attention has focused on change in hay meadows (Critchley *et al.*, 2007; Homburger and Hofer, 2012), mesotrophic grasslands are less well studied, particularly those managed as pasture (Stewart and Pullin, 2008). However, mesotrophic sites can be botanically rich and may be more vulnerable to agricultural intensification than calcareous grasslands because of their higher levels of soil fertility (Hodgson *et al.*, 2005). The management of semi-natural mesotrophic grasslands is often dependent on topography with grazing dominating sites with steeper slopes whilst mowing for field-dried hay will be carried out on flatter ground (Andrieu *et al.*, 2007). Community composition of grassland vegetation varies according to management type (Klimek *et al.*, 2007) so studies which consider sites under different management regimes provide additional important information about long-term change.

Long-term, experimental studies such as the Park Grass experiment and the Steinach Grassland experiment provide detailed, temporal data about different management treatments in grassland systems (Hejcman *et al*., 2014; Silvertown *et al*., 2010). Other approaches to investigating long-term change include re-visitation studies which consider various types of sites sometimes located over a large geographical area. Such studies deliver valuable complementary information to that generated by the monitoring of experimental plots and provide an indication of change over a wider spatial scale. Re-visitation studies have revealed widespread change such as the effects on species richness in coastal vegetation communities around Scotland (Pakeman *et al*., 2016) and a loss of distinctive species in calcareous grasslands in sites across the UK (Bennie *et al*., 2006; Van den Berg *et al.*, 2011). There are fewer studies of mesotrophic grasslands but Critchley *et al* (2007) found a reduction in herb cover in species rich hay meadows at a regional scale.

The present study investigated change in 35 mesotrophic grassland sites first surveyed in the 1980s and 1990s by the UK Nature Conservancy Council. The grasslands included sites which had been consistently managed as either hay meadows or as pastures. It also included sites originally managed as meadows but which had seen a change to more intensive management, and sites where there was no management or only occasional management. It would be expected that a change to more intensive management or to a lack of regular management would be more likely to result in corresponding changes in community composition, a relationship which has been widely discussed (Hodgson *et al.*, 2005; Krause and Culmsee, 2013; Peco *et al.*, 2005; Poschlod *et al.*, 2005).

Re-visitation studies often use quadrat surveys to repeat previous vegetation surveys (Critchley *et al.* 2007; Meyer *et al.*, 2015; Ross *et al.*, 2012). Quadrats enable a standard, repeatable survey method although there is debate about optimum quadrat size and about inconsistencies in the estimation of percent cover (Archaux *et al.*, 2007; Kent, 2012). In the present study repeat quadrat surveys were carried out but baseline data was also available for site species lists for all of the sites included in the study. Whilst the quadrat data account for the principal vegetation communities, whole site species lists can reveal information about the vegetation in atypical parts of a grassland site such as ditches, wetter areas and sloping banks which were often less accessible to livestock or machinery and which can enhance the diversity of the vegetation across the site.

The statistical analysis of data obtained from studies which use stratified random sampling or quadrats placed subjectively in representative stands of vegetation will be more limited than that of data obtained from using an entirely random sampling design (Lajer, 2007). However, it is recognised that there is considerable value in the data from the numerous relevés which have been recorded over many years as part of phytosociological and other vegetation studies, provided that it is analysed and interpreted appropriately (Diekmann, *et al.*, 2007; Hédl, 2007; Lepš and Šmilauer, 2007). A similar approach should be taken with data collected from site species lists which can also be affected by surveyor bias but which can provide important information particularly where resources for surveys are limited (Gordon and Newton, 2006).

This study explored long-term change in the vegetation of 35 mesotrophic grasslands located across an upland region of north-west England. Unlike other revisitation studies it combined a comparison of long-term change in grasslands with different management regimes and used data from two different survey methods.

The study addressed the following questions: (1) Has the overall community composition of grassland vegetation changed? (2) Are there differences in the extent of change between grasslands with different management types? (3) Do the two survey methods provide contrasting information about vegetation change? (4) Which species are the main 'winners' and 'losers'?

Methods

Study area

The study was carried out in the Pennine region of North West England. The study sites were located within an area of approximately 450 km^2 in the valleys of the Forest of Bowland which is an upland area situated at 53°58′N, 2°26′W (Figure 1). The mean annual precipitation for the region is 1294mm, mean January temperature is 4.0°C and mean July temperature is 15.8°C (Met Office, 2016).

Figure 1 Location map

Site selection

35 grassland sites were identified where baseline survey data for both quadrat and species list surveys were available. The data had been collected in the 1980s and 1990s as part of a UK wide grassland survey (Blackstock *et al*., 1999). Part of this nationwide survey focused on mesotrophic lowland (i.e. below the moorland line or lower than approximately 300m above sea level) grasslands in Lancashire and it is this dataset that forms the baseline for the present study (Taylor, 1986.). Grasslands in the original surveys were selected using existing Phase 1 habitat survey records and other local information and were chosen because they were species rich or moderately species rich. The surveys aimed to record sites which were important for conservation and to compare the botanical detail of sites with similar vegetation classifications.

The study incorporated sites from the Forest of Bowland region with contrasting management regimes including 14 sites which had been managed continuously as hay meadows since the original surveys were undertaken. Management details for these sites such as earliest cutting dates, amounts of farmyard manure and dates of removal of grazing stock in the spring can be linked to their inclusion in agri-environment schemes or designation as protected sites. 10 sites had been managed by grazing (cattle, sheep or a mixture of both). There were also 6 sites which were hay meadows at the time of the first survey but which had seen a change in management since the first survey was undertaken. The timing of the change is not known for all of the sites but the current management is more intensive and involves either permanent grazing or cutting for silage rather than hay. The remaining 5 sites are no longer regularly cut or grazed but, again details of the timings of the change are not known for all of the grasslands. The sites were located at altitudes varying from 60m to 280m above sea level. Sites varied in size from 0.2ha to 11.59 ha (Table 1).

In the original surveys the grasslands the grasslands were classified under the UK National Vegetation Classification (NVC) as upland hay meadows MG3 *Anthoxanthum odoratum-Geranium sylvaticum*, floodplain meadows MG4 *Alopecurus pratensis-Sanguisorba officinalis* and lowland hay meadows or pastures MG5 *Cynosurus cristatus-Centaurea nigra* communities (Rodwell, 1992) although the majority of the surveys took place before the NVC was published and none of them were part of the NVC survey itself. These are the main communities but some grasslands would also have supported or still support small areas of other mesotrophic examples. Most of the grasslands belong to the Triseto-Polygonion alliance or are associated with alliances within the Molinio-Arrhenatheretea order (Rodwell *et al*., 2007).

Table 1

Data collection

Repeat surveys (hereafter the second survey) were carried out using the original methods in the summers of 2012 - 2014. The original surveys (hereafter the first survey) followed Nature Conservancy Council guidance and involved the placing of 1x1m quadrats in areas deemed to be representative of the main vegetation communities (Smith *et al.*, 1985). The guidance stated that the quadrats should be placed randomly within each vegetation community although it was acknowledged that this would not always be possible, particularly in smaller stands of vegetation. In the meadow communities a random sampling approach would be straightforward but this might not have been achievable in some of the grazed sites where species rich flushes and other smaller vegetation stands where surveyed.

Sketch maps of the locations of the first survey quadrats (see Smith *et al.*, 1985 for an example map) were used to locate the quadrats in the second survey. The placing of the second survey quadrats followed the original approach by selecting areas representative of the main communities using the sketch maps and detailed descriptions of the vegetation to ensure they were in the correct area of the site. The number of quadrats varied depending on the size and complexity of the sites (Table 1). In the meadows quadrats were estimated to be within approximately 25m of the original location although this would vary according to the size of site and number of quadrats. The grazed sites were often more variable with a mosaic of various vegetation communities which accounted for the higher number of quadrats in the original surveys, but in these sites the re-location of the quadrat was aided by descriptions of particular vegetation stands such as a species rich flush or by proximity to a feature such as a stream. Presence and abundance, using the Domin scale, of all vascular plants were recorded.

In addition to the quadrat surveys the first survey involved the compilation of a species list covering all areas of the site on and within the site boundary (so vegetation in boundary hedges was included). Site boundaries included hedges, dry stone walls, post and wire fences and watercourses or ditches. None of these boundaries had been removed or re-positioned since the first surveys were undertaken. The NCC guidelines did not require surveyors to time the species list survey but there was a requirement to include all of the vegetation communities on the site.

Data analysis

An exploratory approach to data analysis was taken because it could not be assumed that random sampling methods had been used for all of the quadrats or for the collection of species list data. To analyse differences in community composition Non Metric Multi-dimensional scaling (NMDS) ordinations were undertaken on the first and second surveys quadrat and species list data. The Domin scores recorded in the quadrat surveys were converted to percentage values by using midpoint of each Domin category. The Bray Curtis dissimilarity matrix was used and the NMDS ordinations were carried out using the metaMDS function in the vegan package in R (Oksanen, *et al.,* 2013). The NMDS ordinations examined community composition by year and then separate ordinations were carried out on the quadrat data to investigate the four management types, i.e: meadows, grazed sites, former meadows with more intensive current management, and sites which had little or no management.

To investigate patterns in community composition revealed by the two survey methods (quadrat surveys and species list surveys) the quadrat data were first converted from abundance data to presence/absence data so that they were analysed in the same format as the species list data. NMDS ordinations for the two survey types were then compared using Procrustes analysis in the vegan package (Oksanen *et al*., 2013). Procrustes analysis is used to investigate the extent to which there is a fit between one ordination or dataset and another and produces a correlation score indicating the extent of the fit based on the distances between the sampling points or sites. A low score would indicate that there was little similarity between the two ordinations and *vice versa*. Protest does return *P* values but large datasets can affect the validity of *P* values and it is recommended that the *r* value is more useful in interpreting the outcome of the test (Oksanen, *et al.*, 2013).

To analyse species losses and gains, species were ranked according to the frequency at which they had been recorded by site in the first and second surveys in both quadrats and species lists.

In the UK guidance is issued for the monitoring of protected mesotrophic grassland sites (JNCC, 2004). The guidance lists species for each grassland community which are considered as positive indicators whose presence is indicative of favourable conservation status. These indicator species are used to evaluate the conservation value of particular grassland communities and to address whether the target vegetation community is being maintained or not. The frequency of positive and negative indicator species by site were compared for the first and second surveys. Indicator species are listed in Appendix 1.

To assess whether there was any indication of change in functional type in the increased and decreased species mean values for Ellenberg Indicator Values (EIVs) for the British plants for light (L), moisture (F), reaction (R) and fertility (N) were calculated for the most increased and decreased species (Hill *et al*., 1999). Weightings were not used for the EIVs because there were no abundance data for the species lists. Ellenberg values can give an indication of changes in environmental conditions and are useful as a proxy measure when no soil data is available as was the case for these surveys. Calculations of Grime's C-S-R plant strategy scores using the tool developed by Hunt *et al.* (2004) were also undertaken and assigned to the most increased and decreased species. The modal C-S-R type was calculated.

All analysis was carried out in R version 3.1.2 (R Development Core Team, 2014).

Results

In the quadrat survey the total number of species recorded across all 35 sites was 152 from the first surveys and 144 from the second survey (a decrease of 5.26%). In the species list survey the totals were 268 from the first survey and 229 from the second survey (a decrease of 14.55%).

The NMDS ordination plots do not show a distinct separation of survey sites by year for either the quadrat data or the species list data (fig 2a and 2b) indicating that there is little difference in overall community composition between the two survey years.

Figure 2a NMDS ordination of quadrat data for the first and second surveys. Points represent grassland sites. Stress = 0.22.

Figure 2b NMDS ordination of species list data for the first and second surveys. Points represent grassland sites. Stress = 0.22.

The NMDS plots for management types show that there is some differentiation between the survey years (Figs. 3 and 4). In the meadow sites there is some separation along both axes for the quadrat data (Fig. 3a) with less difference between the two years in the species list data (Fig. 3b). In the grazed sites the differences between the two years are less distinct although two or three sites in each plot appear to have a different community composition than the majority of the grazed sites. Figs. 4a and 4b shows that change has taken place in sites which were managed as hay meadows at the time of the first survey and are now more intensively managed for silage or by permanent grazing. There is a less distinct pattern in the sites with little or no management (Figs. 4c and 4d).

Figure 3. NMDS ordinations of quadrat and species list survey data for the two survey years by management type. Plot a shows quadrat data for meadow sites (stress = 0.18), plot b shows species list data for meadow sites (stress = 0.17), plot c shows quadrat data for grazed sites (stress = 0.19) and plot d shows species list data for grazed sites (stress = 0.19).

Figure 4. NMDS ordinations of quadrat and species list survey data for the two survey years by management type. Plot a shows quadrat data for former meadow sites which are now more intensively managed (stress = 0.13), plot b shows species list data for intensively managed former meadow sites (stress = 0.13), plot c shows quadrat data for sites with little or no management (stress = 0.10) and plot d shows species list data for sites with little or no management (stress = 0.10).

The two quadrat and species list NMDS ordinations were not found to have a similar configuration. The Protest permutation test returned an r value of 0.27 which suggested that there was little correlation between the two ordinations. This result indicates that the two survey methods revealed contrasting results in terms of community composition.

More species had shown a decrease than an increase in terms of the number of site records (Tables 2 and 3). Table 2 shows the 25 species which showed the greatest decrease for both the quadrat and species list data (see Appendix 2 for a full species list). 11 of the 25 species appear in both the quadrat and species list data. Examples of species which are regarded as positive indicators for mesotrophic grassland were found in both sets of data (e.g. *Anemone nemorosa* and *Leontodon hispidus*). Some negative indicator species were also found to have decreased (e.g. *Dactylis glomerata)*. Species showing the most increases in site records are shown in Table 3. Fewer species had shown a substantial increase in site records, particularly in the quadrat data, but there were some examples of positive (eg. *Euphrasia* species) and negative indicator species (eg *Juncus effusus)*.

The analysis of increased and decreased species showed that there were higher EIV scores for light and moisture in the increased species for both quadrat and species list data (Table 4). For reaction (pH) there was a lower score in the increased quadrat species than the decreased but a higher score in the increased species list species. There was a similar pattern for fertility scores with a lower score for the increased quadrat species when compared to the most decreased species. The fertility score for the most increased species for the species list data appears to be substantially greater than that for the most decreased species although this was not tested statistically. Modal types for C-S-R signatures were different in the most increased species than the decreased species for both the quadrat data and the species list data with a shift away from the stress tolerator type.

Table 2

Table 3

Table 4

Discussion

Analysis of community composition

Taken as a whole the community composition of the 35 grassland sites had remained similar between the two survey years based on both the quadrat surveys and the species list surveys. This finding does not reflect the accounts of significant change in other grassland re-visitation studies (Bennie *et al.,* 2006; Bühler and Roth, 2011). The overall finding of limited change in the mesotrophic grasslands included in the present study may suggest that they are more resilient to change than other grassland habitats where the negative impacts of atmospheric nitrogen deposition and other sources of eutrophication on species richness or diversity have been greater (Stevens *et al*., 2010; Van den Berg *et al.*, 2011). Differences in the responses of grassland habitats to nitrogen deposition have been identified but the results are influenced by several factors including the baseline nutrient levels of the grasslands in the study (Maskell, *et al.*, 2010) and the varying effect of reduced or oxidised forms of nitrogen on the component species of acidic, calcareous or mesotrophic grassland communities (Van den Berg *et al.*, 2016).

Analysis by management type

Analyses of the community composition of the meadow sites in the first and second surveys indicated that there had been more change identified through the quadrat surveys than by the species list surveys. All of the meadow sites are subject to statutory protection and/or higher tier agri-environment schemes (AES) and have similar management regimes. It is possible that a particular aspect of this management regime is the reason for this change to the meadow community rather than a more widespread environmental impact which may have been more likely to have an impact on vegetation across the site. Another factor could be the effect of the isolation of populations of plants within the main meadow community since these sites are few in number and have a fragmented distribution. Detailed investigations of drivers of change are outside the scope of this study but more research into the significance of potential influences such as management, the fragmented distribution of sites, site location factors (eg altitude, aspect) as well as wider environmental factor such as nitrogen deposition would be valuable.

There is less clear evidence of change in the grazed sites although two sites from the second survey in the quadrat plot (Fig. 3c) show some separation from the others. One of these sites included plants associated with mire communities. The other site was being affected by encroachment of the woodland adjacent to it and supported woodland as well as grassland species when the second survey was undertaken. In the species list plot (Fig. 3d) some of the first survey sites show a degree of separation. Losses of species richness were recorded on these sites during the second survey which would account for differences in community composition. It was expected that overall there would be less similarity in the grazed sites due to the greater variation in terms of topography, hydrology and soil conditions, and in their management where livestock type, stocking density and timing of grazing could all influence the vegetation from site to site. However, this does not appear to be the case according to the data collected for this study. Unlike the meadows only three of the pasture sites are protected with the others either in lower tier AES schemes, which are less demanding in the management of grasslands for conservation (Natural England, 2013a; 2013b), or not part of any AES agreement but this lack of a conservation framework for management does not appear to have led to significant change. The NMDS ordinations are valuable for comparing community composition across several sites but they are less useful in detecting fine scale changes which could be occurring within these sites. Hutson (1999) stressed the importance of scale in patterns of vegetation diversity and demonstrated that local conditions can influence regional diversity but such influences can be complex and are dependent on the scale of the study and the type of community.

It was expected that there would be significant change in the vegetation of the grasslands which had seen a change to a more intensive management regime since it is well documented that grasslands require regular low intensity management to maintain botanical diversity (Cuelmans *et al*., 2013; Klimek *et al.*, 2007; Snoo *et al*., 2012). These sites do appear to have experienced the most change although there is not a complete separation of the two survey years. However, the small sample size of the changed sites means that the results have to be treated with some caution. Reference has already been made to the variations in site characteristics in pastures and the distinctiveness of individual sites was also a feature of the changed and unmanaged sites. For example one heavily-grazed former meadow site had retained many of the indicator species in the short sward whilst another with similar management had new records of some meadow indicators. Information on the dates for the changes in management was not available but research has shown that site management history and other small scale factors such as the current and past land use history of neighbouring sites as well as hydrological and soil conditions can all have a significant effect on current species diversity and composition (Gustavsson *et al*., 2007 Kalusová *et al.*, 2009, Reitalu *et al.*, 2009).

There is some evidence of change in the unmanaged sites although, again the small sample size must be taken into account. The lack of regular management appeared to have had an impact on species with a lower growth habit such as *Trifolium repens* and *Luzula campestris*. This is consistent with a study by Pavlů *et al.* (2011) which compared mown and unmanaged grasslands and reported similar results where graminoids and forbs with a short growth habit occurred less frequently in unmanaged plots.

Findings from quadrat and species list surveys

In total more species were recorded in the species list surveys which was expected because the quadrat survey data is a sub-sample of the whole site. In the changed sites, for example, some species not found in the main sward had been retained on steeper banks at the edges of the sites. Some rare and uncommon species were picked up in the species list survey including *Primula farinosa, Platanthera chlorantha, Cirsium heterophyllum* and *Genista tinctoria* which have very few local records and are declining at the national level (Greenwood, 2012; Preston *et al.*, 2002). The comparison of the data resulting from the two survey methods showed that they had identified differences in terms of community composition. These differences can be explained by the fact that the species list survey required that all vegetation communities on the site were included. Features such as streams, ditches, areas close to a woodland boundary, gateways where there was evidence of eutrophication or more heavily trampled areas or small areas of acid or calcareous grassland which were not part of the quadrat survey were present on some sites. It is acknowledged that the effect of the sampling methods used should also be considered here. Surveyor bias and subjectivity will have some influence particularly in the compilation of the species lists so care is needed in the interpretation of the results. Ideally monitoring of long-term change should minimise sampling bias and error and the approach taken by Critchley & Poulton (1998) illustrates the value of precision and accounting for the optimum monitoring scale for different species. However, most revisitation studies aim to replicate the methods of the original survey so there is a trade-off between the value of the long-term data and the limitations imposed by the original survey design.

Species losses and gains

The changes in species records suggest a mixed picture in terms of the maintenance of the target plant communities of species rich mesotrophic sites. There were losses of some grassland species of conservation interest such as *Alchemilla glabra* which was only found in quadrats on 4 sites in the second survey (compared to 15 in the first), although losses recorded in the species list survey were less widespread (a decrease of 21 to 17 sites). Gains in positive grassland indicator species were also recorded (e.g. for *Euphrasia* species) but there were fewer gains than losses. There were losses and gains in site records for negative indicator species such as *Dactylis glomerata* which saw a substantial reduction in the quadrat survey and *Urtica dioica* which increased from 14 to 24 sites in the species list survey.

Some losses of positive indicators would be expected given the change to more intensive management in the former meadow sites but they may also reflect the impact of particular management prescriptions in sites which are being managed for conservation. For example, *Ranunculus repens* was recorded on all 35 sites and in most of the quadrats in the second survey. A study which investigated the control of *R. repens* and *Juncus* species (which also showed a large increase) found that early summer mowing dates were effective in reducing the abundance of *R. repens* whilst an autumn cut reduced *Juncus* species (Marriott *et al*., 2003). These cutting dates would not be permitted under AES management prescriptions for meadow sites.

The higher mean Ellenberg N score for the increased species in the species list data is mainly a result of increases in species like *Urtica dioica*, *Rumex obtusifolius* and *Galium aparine* which have Ellenberg N scores of 8 or 9. The Ellenberg N values in the increased species in the quadrat data were lower which could suggest that the species list scores were a result of localised increases of particular species. These species are also competitor species so their increases also influence the C-S-R scores. Ellenberg values and C-S-R strategies are useful but they may not take into account some of the more subtle changes in the dynamics of these grassland communities, changes which may also be too fine scale for a regional analysis of community composition in all of the 35 sites in this study. Suding *et al.* (2005) found that whilst species richness always declined when soil nitrogen increased, there were varying responses among different plant traits and habitat types. Rare species and nitrogen fixing forbs were vulnerable to increases in fertility but so too were some perennials because of their conservative growth strategies in comparison to other more rapidly growing species which used the increased nitrogen more effectively. Conservation approaches which enhance rare species but also take account of the dynamics of different functional groups will require a greater understanding of these fine scale processes and how they relate to regional patterns of diversity, along with further long-term study to monitor their effectiveness.

Conclusion

The community composition of the 35 grassland sites had not seen a marked change at the regional level over the period of study. This is in contrast to the substantial changes noted in other re-visitation grassland studies. However important finer scale change was identified and grassland management had an influence on plant communities. Different survey methods provided contrasting information about the grassland sites and the combination of quadrat surveys and species lists can provide valuable information about key vegetation communities as well as other aspects of the site such as the presence of rare species. There were losses and gains of positive indicator species as well as changes in negative species but overall there were more losses than gains. This is a concern and more research is needed to understand why such losses are occurring particularly in sites which are protected and managed for conservation

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TABLES

Table 1. Site details

Site ID	Management type	Size (ha)	Altitude	No. of quadrats
AM	former meadow	1.8	185	3
BG	meadow	5.47	180	1
BG2	meadow	2.2	180	1
BG3	meadow	3.1	180	2
BS (3 fields)	meadow	7.65	150	12
BS1	meadow	2.3	180	2
BS3	grazed	1.2	170	3
CB	meadow	0.54	60	4
DH	meadow	0.4	190	2
FH	meadow	1.63	105	2
FHM	meadow	3.33	201	4
HHL	unmanaged	10.3	195	6
HHM	unmanaged	0.3	105	2
LBL	former meadow	1.7	140	2
LCB	grazed	6.0	180	3
LCM	meadow	5.26	190	2
LHBS	grazed	0.76	130	2
LHG	grazed	2.2	100	3
LRS	unmanaged	0.2	120	2
LSM	former meadow	1.1	230	1
LWM	unmanaged	3.6	105	2
MM (2 fields)	meadow	9.09	155	9
MM2	grazed	0.7	160	3
NI	meadow	2.09	125	6
NKM	grazed	3.9	180	6
OWP	grazed	0.3	160	6
PHB	unmanaged	0.5	135	2
PP	grazed	1.8	150	10
RH	former meadow	1.8	80	2
SFP	grazed	4.5	230	11
SM	meadow	3.63	200	2
SPM	grazed	1.4	280	6
TB (5 fields)	meadow	11.87	155-180	7
TL	former meadow	0.4	220	2

TSM	former meadow	6.4	185	3

Table 2 Decreases in number of records of species at grassland sites for quadrat survey data and species list data. The 25 most decreased species are shown. Species in bold are examples of positive indicators for UK mesotrophic grasslands and species with an asterisk* are examples of negative indicators (JNCC, 2004).

Quadrat survey data				Species list survey data			
Species	No of site records (1st survey)	No of site records (2nd survey)	Decrease in site frequency	Species	No of site records (1st survey)	No of site records (2nd survey)	Decrease in site frequency
Luzula campestris	20	6	-14	*Achillea ptarmica*	22	5	-17
Poa pratensis	14	2	-12	*Poa pratensis*	18	1	-17
Alchemilla glabra	**15**	**4**	**-11**	*Ficaria verna*	17	1	-16
Centaurea nigra	**27**	**16**	**-11**	*Luzula campestris*	25	12	-13
Achillea ptarmica	12	2	-10	*Achillea millefolium*	25	13	-12
*Dactylis glomerata**	20	10	-10	*Cardamine pratensis*	29	18	-11
*Phleum pratense**	17	7	-10	*Angelica sylvestris*	16	6	-10
Bellis perennis	18	9	-9	*Ajuga reptans*	13	4	-9
Bromus hordeaceus	13	4	-9	***Anemone nemorosa***	**9**	**0**	**-9**
Ficaria verna	12	3	-9	*Avenula pubescens*	14	5	-9
Conopodium majus	**19**	**11**	**-8**	***Alchemilla xanthochlora***	**8**	**0**	**-8**
Hypochaeris radicata	14	6	-8	*Cirsium vulgare**	8	0	-8
Leontodon hispidus	**13**	**7**	**-6**	*Festuca ovina*	16	8	-8
Plantago lanceolata	33	27	-6	***Leontodon hispidus***	**19**	**11**	**-8**
Prunella vulgaris	19	13	-6	*Ranunculus bulbosus*	9	1	-8
*Trifolium repens**	31	25	-6	*Bromus hordeaceus*	14	7	-7
Ajuga reptans	6	1	-5	***Centaurea nigra***	**30**	**23**	**-7**
Alchemilla xanthochlora	**5**	**0**	**-5**	***Conopodium majus***	**24**	**17**	**-7**
Anemone nemorosa	**5**	**0**	**-5**	*Phleum pratense**	21	14	-7
*Juncus inflexus**	6	1	-5	*Plantago major*	12	5	-7
Lathyrus pratensis	**22**	**17**	**-5**	*Vicia cracca*	21	14	-7
Ranunculus bulbosus	5	0	-5	*Agrostis capillaris*	34	28	-6
Sanguisorba officinalis	**21**	**16**	**-5**	*Cerastium glomeratum*	7	1	-6
Achillea millefolium	13	9	-4	*Heracleum sphondylium*	18	12	-6
Agrostis canina	4	0	-4	*Tussilago farfara*	8	2	-6

Table 3 Increases in number of records of species at grassland sites for quadrat survey data and species list data. The 15 most increased species are shown. Species in bold are examples of positive indicators for UK mesotrophic grasslands and species with an asterisk* are examples of negative indicators (JNCC, 2004).

Quadrat survey data				Species list survey data			
Species	No of sites recorded (1st survey)	No of sites recorded (2nd survey)	Gain in site frequency	Species	No of sites recorded (1st survey)	No of sites recorded (2nd survey)	Gain in site frequency
Ranunculus repens	20	31	11	*Alopecurus geniculatus*	8	19	11
Euphrasia species	**8**	**13**	**5**	***Galium palustre***	**6**	**17**	**11**
Galium palustre	**3**	**7**	**4**	*Juncus effusus**	15	25	10
Glyceria declinata	0	3	3	*Urtica dioica**	14	24	10
Lotus corniculatus	**13**	**16**	**3**	*Alopecurus pratensis*	14	23	9
Luzula multiflora	2	5	3	*Dactylorhiza fuchsii*	10	18	8
Myosotis discolor	5	8	3	*Juncus articulatus**	12	20	8
Alopecurus geniculatus	1	3	2	*Ranunculus repens*	28	35	7
*Juncus effusus**	5	7	2	*Myosotis discolor*	12	18	6
Trifolium dubium	1	3	2	*Poa trivialis*	26	32	6
Vicia cracca	8	10	2	***Euphrasia species***	**13**	**17**	**4**
Trifolium medium	0	1	1	*Galium aparine*	2	6	4
Triglochin palustre	0	1	1	*Glyceria declinata*	1	5	4
*Urtica dioica**	1	2	1	*Poa annua*	4	7	3
Vaccinium oxycoccos	0	1	1	*Rumex obtusifolius**	15	18	3

Table 4 Mean Ellenberg Indicator Values (EIV) and C-S-R types for most increased and decreased species. Eb L = light; Eb F = moisture; Eb R = reaction; Eb N = fertility. C = competitor; S = stress tolerator; R = ruderal.

	Mean EIV				Modal C-S-R type
	Eb L	Eb F	Eb R	Eb N	
Most decreased species (quadrat data)	6.92	5.36	5.88	4.36	CSR
Most increased species (quadrat data)	7.07	6.50	5.36	4.29	CR

Most decreased species (species list data)	6.80	5.36	5.88	4.56	CSR
Most increased species (species list data)	6.93	6.43	6.29	6.21	CR

FIGURES

Fig 1.

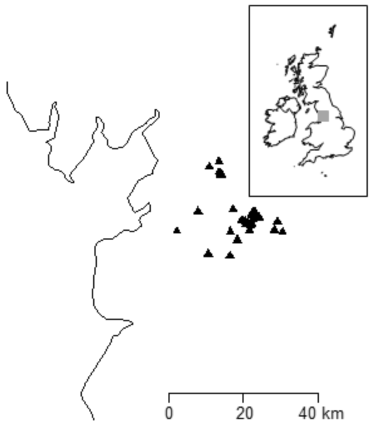


Fig 2a.

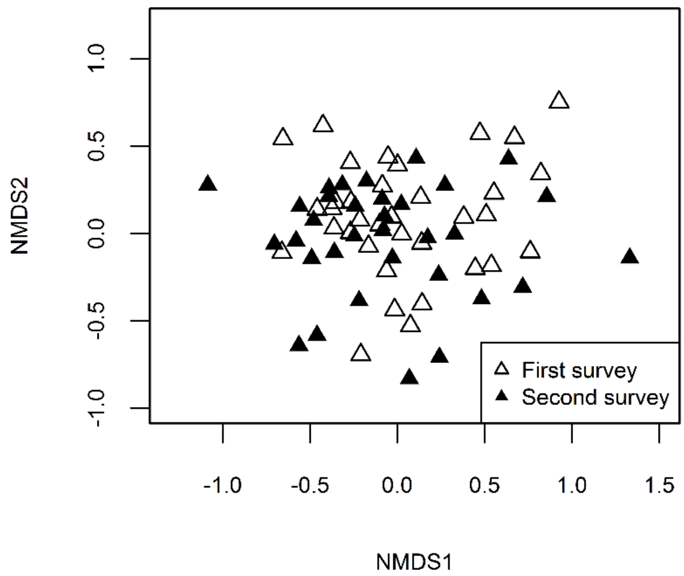

NMDS2
NMDS1
First survey
Second survey

Fig 2b

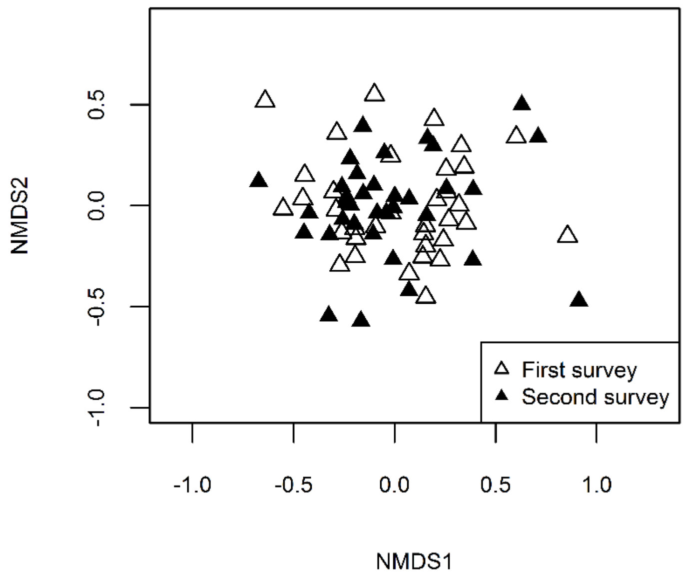

NMDS2
NMDS1
First survey
Second survey

Fig 3

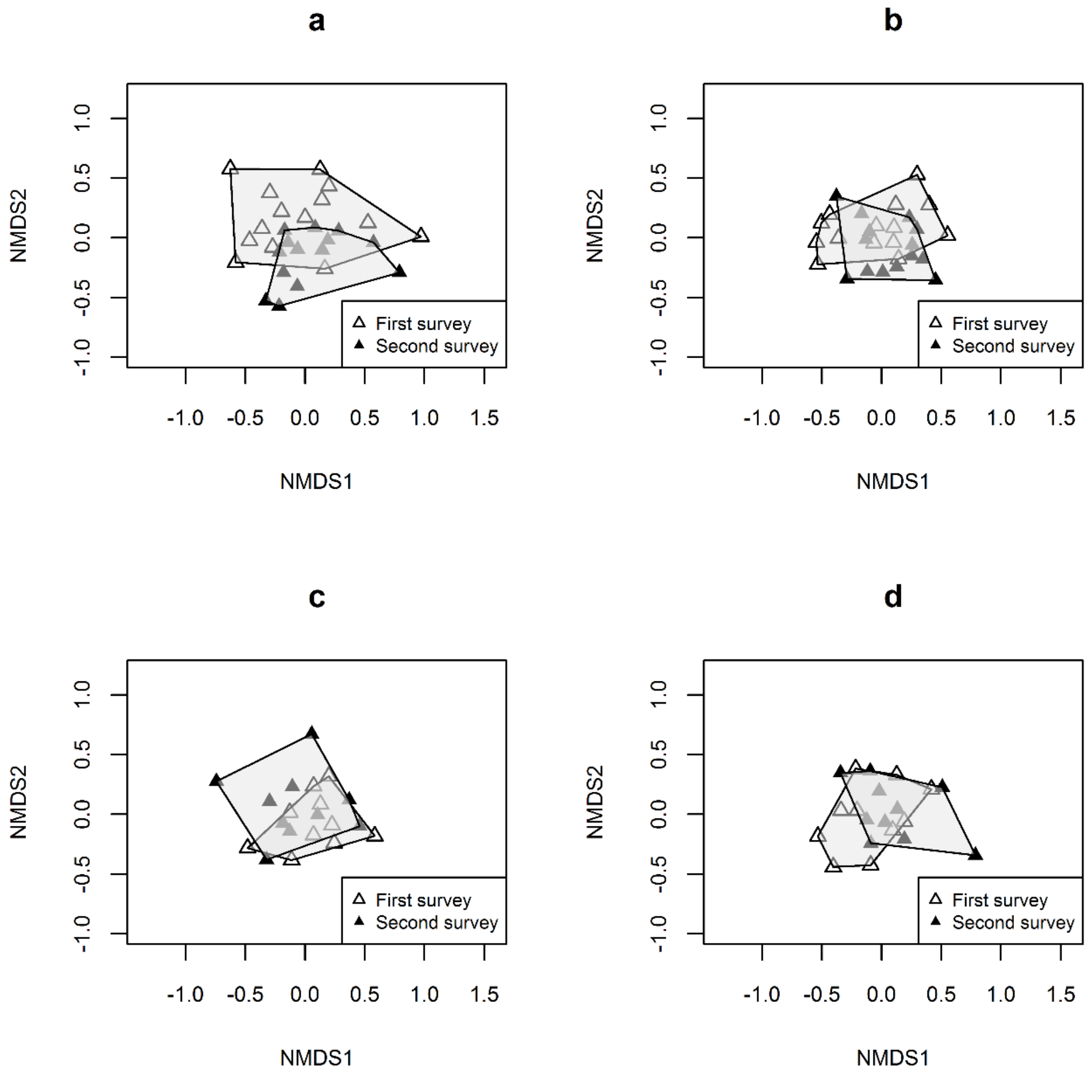
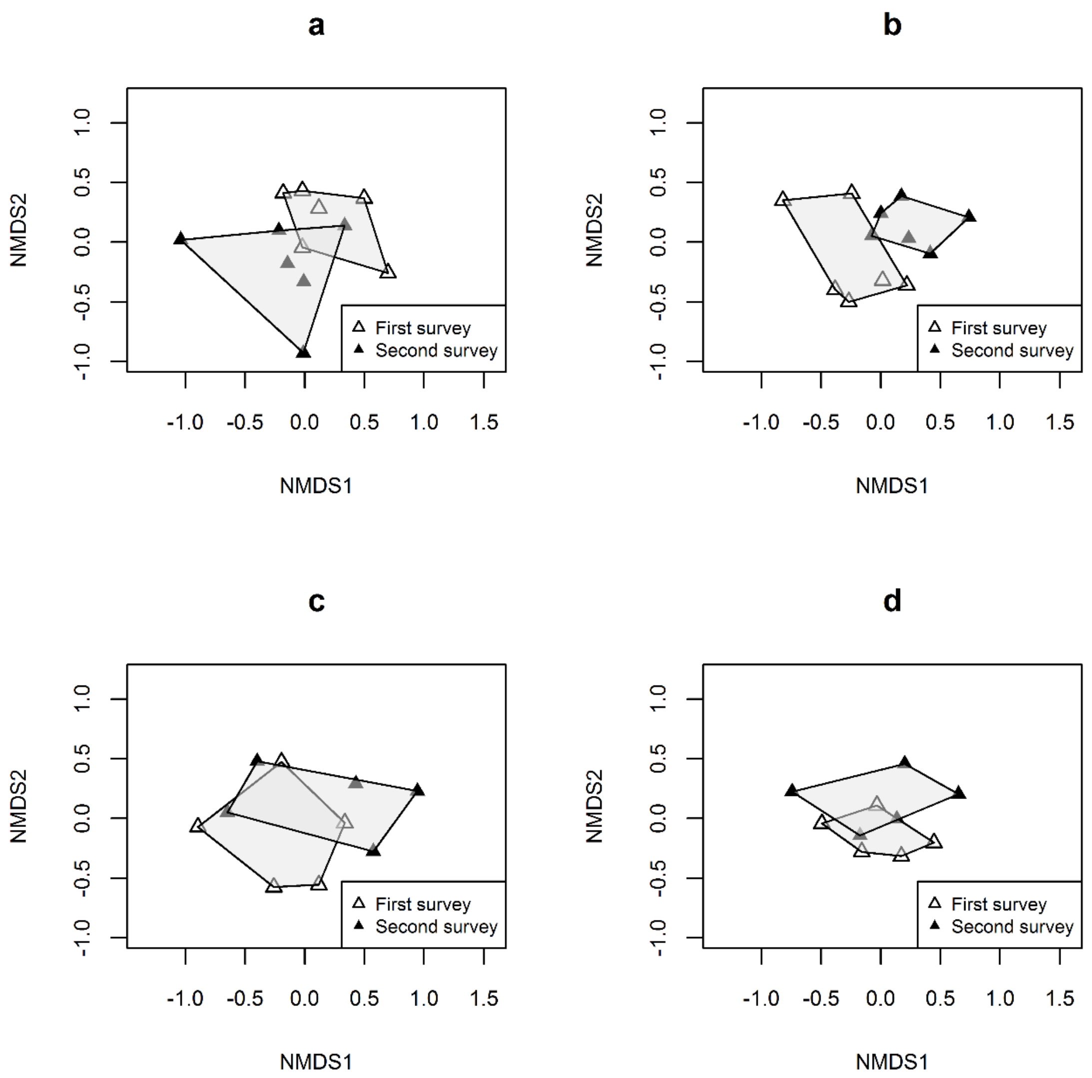


Fig 4



Appendix1: Examples of positive indicator species for MG3, MG4 and MG5 grasslands

Agrimonia eupatoria
Alchemilla spp.
Anemone nemorosa
Betonica officinalis
Centaurea nigra
Cirsium heterophyllum
Conopodium majus
Euphrasia spp.
Filipendula ulmaria
Galium verum,
Genista tinctoria
Geranium sylvaticum
Geum rivale
Lathyrus linifolius
Lathyrus pratensis,
Leontodon spp.

Lotus corniculatus
Oenanthe silaifolia,
Persicaria Bistorta
Pimpinella saxifrage
Polygala spp.
Potentilla erecta
Poterium sanguisorba
Primula veris,
Rhinanthus minor
Sanguisorba officinalis
Serratula tinctoria,
Silaum silaus
Succisa pratensis
Thalictrum Flavum
Trollius europaeus.

Appendix 2: Full species list

Acer pseudoplatanus
Achillea millefolium
Achillea ptarmica
Agrimonia eupatoria
Agrostis canina
Agrostis capillaris
Agrostis stolonifera
Ajuga reptans
Alchemilla filicaulis
Alchemilla glabra
Alchemilla mollis
Alchemilla xanthochlora
Allium ursinum
Alnus glutinosa
Alopecurus geniculatus
Alopecurus pratensis
Anagallis tenella
Anemone nemorosa
Angelica sylvestris
Anthoxanthum odoratum
Anthriscus sylvestris
Arctium minus
Arrhenatherum elatius
Athyrium filix-femina
Avenula pubescens
Bellis perennis
Betonica officinalis
Betula pendula
Betula pubescens
Blechnum spicant
Briza media
Bromus hordeaceus
Caltha palustris
Campanula rotundifolia
Capsella bursa-pastoris
Cardamine amara
Cardamine flexuosa
Cardamine pratensis
Carex spp.
Carex acutiformis
Carex binervis
Carex caryophyllea
Carex demissa
Carex disticha
Carex echinata
Carex flacca
Carex hirta

Carex hostiana
Carex lepidocarpa
Carex leporina
Carex nigra
Carex pallescens
Carex panicea
Carex pilulifera
Carex pulicaris
Carex remota
Carex sylvatica
Centaurea nigra
Cerastium fontanum
Cerastium glomeratum
Chamerion angustifolium
Chryosplenium oppositifolium
Circaea lutetiana
Cirsium arvense
Cirsium heterophyllum
Cirsium palustre
Cirsium vulgare
Comarum palustre
Conium maculatum
Conopodium majus
Corylus avellana
Crataegus monogyna
Crepis capillaris
Crepis paludosa
Cruciata laevipes
Cynosurus cristatus
Dactylis glomerata
Dactylorhiza fuchsii
Dactylorhiza spp
Dactylorhiza maculata
Dactylorhiza purpurella
Danthonia decumbens
Deschampsia cespitosa
Deschampsia flexuosa
Digitalis purpurea
Drosera rotundifolia
Dryopteris affinis agg.
Dryopteris carthusiana
Dryopteris dilatata
Dryopteris filix-mas
Eleocharis palustris
Elymus caninus
Elytrigia repens
Epilobium hirsutum
Epilobium montanum

Epilobium palustre
Epilobium parviflorum
Equisetum arvense
Equisetum palustre
Equisetum sylvaticum
Eriophorum angustifolium
Erica tetralix
Euphrasia spp.
Fagus sylvatica
Festuca ovina
Festuca rubra
Festuca x Festulolium
Ficaria verna
Filipendula ulmaria
Fraxinus excelsior
Galium aparine
Galium palustre
Galium saxatile
Galium verum
Genista tinctoria
Geranium pratense
Geranium robertianum
Geranium sylvaticum
Geum rivale
Geum urbanum
Glechoma hederacea
Glyceria declinata
Glyceria fluitans
Heracleum sphondylium
Hieracum spp.
Holcus lanatus
Holcus mollis
Hyacynthoides non-scripta
Hydrocotyle vulgaris
Hypericum pulchrum
Hypericum tetrapterum
Hypochaeris radicata
Ilex aquifolium
Impatiens glandulifera
Juncus acutiflorus
Juncus articulatus
Juncus bufonius
Juncus bulbosus
Juncus compressus
Juncus conglomeratus
Juncus effusus
Juncus inflexus
Juncus squarrosus

Koeleria macrantha
Lapsana communis
Larix spp.
Lathyrus linifolius
Lathyrus pratensis
Leontodon hispidus
Leucanthemum vulgare
Linum catharticum
Lolium perenne
Lonicera periclymenum
Lotus corniculatus
Lotus pedunculatus
Luzula campestris
Luzula multiflora
Lysimachia nemorum
Lysimachia nummularia
Malus sylvestris
Matricaria discoidea
Mentha aquatica
Mentha arvensis
Mercuralis perennis
Mimulus guttatus
Molinea caerulea
Montia fontana
Mycelis muralis
Myosotis arvensis
Myosotis discolor
Myosotis laxa
Myosotis spp.
Myosotis scorpioides
Myosotis secunda
Myrrhis odorata
Nardus stricta
Nasturtium officinale
Neottia ovata
Odontites vernus
Ophioglossum vulgatum
Orchis mascula
Oreopteris limbosperma
Oxalis acetosella
Parnassia palustris
Pedicularis palustris
Pedicularis sylvatica
Persicaria bistorta
Persicaria maculosa
Petasites hybridus
Phalaris arundinacea
Phleum pratense

Pilosella officinarum
Pimpinella saxifraga
Pinguicula vulgaris
Plantago lanceolata
Plantago major
Plantago media
Platanthera chlorantha
Poa annua
Poa pratensis
Poa trivialis
Polygala serpyllifolia
Polygonum aviculare
Polystichum spp.
Populus tremula
Potamogeton polygonifolius
Potentilla anserina
Potentilla erecta
Potentilla reptans
Potentilla sterilis
Poterium sanguisorba
Primula farinosa
Primula vulgaris
Prunella vulgaris
Prunus spinosa
Pteridium aquilinum
Pulicaria dysenterica
Ranunculus acris
Ranunculus bulbosus
Ranunculus flammula
Ranunculus repens
Rhinanthus minor
Ribes spp.
Rosa arvensis
Rosa canina
Rosa spp.
Rubus fruticosus agg.
Rumex acetosa
Rumex acetosella
Rumex conglomeratus
Rumex crispus
Rumex obtusifolius
Quercus spp.
Sagina spp.
Salix cinerea
Salix spp.
Salvia verbenaca
Sanguisorba officinalis
Schedonorus arundinaceus

Schedonorus giganteus
Schedonorus pratensis
Scorzoneroides autumnalis
Scrophularia nodosa
Senecio aquaticus
Serratula tinctoria
Silene dioica
Silene flos-cuculi
Sorbus aucuparia
Sorbus spp.
Stachys palustris
Stachys sylvatica
Stellaria alsine
Stellaria graminea
Stellaria holostea
Stellaria media
Succisa pratensis
Symphytum tuberosum
Taraxacum offincinale agg.
Taxus baccata
Teucrium scorodonia
Torilis japonica
Trifolium campestre
Trifolium dubium
Trifolium medium
Trifolium pratense
Trifolium repens
Triglochin palustris
Trisetum flavescens
Trollius europaeus
Tussilago farfara
Ulex europaeus
Ulmus spp.
Urtica dioica
Vaccinium myrtillus
Vaccinium oxycoccos
Valeriana dioica
Valeriana officinalis
Veronica anagallis-aquatica
Veronica arvensis
Veronica beccabunga
Veronica chamaedrys
Veronica officinalis
Veronica scutellata
Veronica serpyllifolia
Vicia cracca
Vicia sativa
Vicia sepium

Viola palustris
Viola riviniana

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