

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

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13

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

25

26 **Abstract**

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

46

47

48 **Keywords**

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

51

52

53 **Introduction**

54 Species-rich grasslands support a rich diversity of vegetation but they are particularly  
55 vulnerable to change (Habel *et al.*, 2013). In Europe the maintenance of diversity in such  
56 grasslands usually requires an extensive agricultural management regime (Wesche *et al.*,  
57 2012), so the widespread adoption of intensive agricultural practices and the abandonment of  
58 more inaccessible or unproductive grasslands has resulted in the loss of the majority of  
59 species rich grasslands in most European countries (Stoate *et al.*, 2009). Studies which record  
60 long-term change in the remaining species rich grasslands are rare but can make a valuable  
61 contribution to our understanding of ecological processes as well as helping to inform  
62 management approaches (Magurran, *et al.*, 2010; Silvertown *et al.*, 2010).

63

64 Some of the most diverse vegetation communities are found in calcareous grasslands and  
65 these habitats have been the subject of studies concerning change resulting from various  
66 influences and at different scales (Bennie *et al.*, 2006; Diekmann *et al.*, 2014; Van den Berg  
67 *et al.*, 2011). Although some attention has focused on change in hay meadows (Critchley *et*  
68 *al.*, 2007; Homburger and Hofer, 2012), mesotrophic grasslands are less well studied,  
69 particularly those managed as pasture (Stewart and Pullin, 2008). However, mesotrophic sites

70 can be botanically rich and may be more vulnerable to agricultural intensification than  
71 calcareous grasslands because of their higher levels of soil fertility (Hodgson *et al.*, 2005).  
72 The management of semi-natural mesotrophic grasslands is often dependent on topography  
73 with grazing dominating sites with steeper slopes whilst mowing for field-dried hay will be  
74 carried out on flatter ground (Andrieu *et al.*, 2007). Community composition of grassland  
75 vegetation varies according to management type (Klimek *et al.*, 2007) so studies which  
76 consider sites under different management regimes provide additional important information  
77 about long-term change.

78

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

91

92 The present study investigated change in 35 mesotrophic grassland sites first surveyed in the  
93 1980s and 1990s by the UK Nature Conservancy Council. The grasslands included sites

94 which had been consistently managed as either hay meadows or as pastures. It also included  
95 sites originally managed as meadows but which had seen a change to more intensive  
96 management, and sites where there was no management or only occasional management. It  
97 would be expected that a change to more intensive management or to a lack of regular  
98 management would be more likely to result in corresponding changes in community  
99 composition, a relationship which has been widely discussed (Hodgson *et al.*, 2005; Krause  
100 and Culmsee, 2013; Peco *et al.*, 2005; Poschlod *et al.*, 2005).

101

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

112

113 The statistical analysis of data obtained from studies which use stratified random sampling or  
114 quadrats placed subjectively in representative stands of vegetation will be more limited than  
115 that of data obtained from using an entirely random sampling design (Lajer, 2007). However,  
116 it is recognised that there is considerable value in the data from the numerous relevés which  
117 have been recorded over many years as part of phytosociological and other vegetation

118 studies, provided that it is analysed and interpreted appropriately (Diekmann, *et al.*, 2007;  
119 Hédli, 2007; Lepš and Šmilauer, 2007). A similar approach should be taken with data  
120 collected from site species lists which can also be affected by surveyor bias but which can  
121 provide important information particularly where resources for surveys are limited (Gordon  
122 and Newton, 2006).

123

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

128

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

134

## 135 **Methods**

### 136 ***Study area***

137 The study was carried out in the Pennine region of North West England. The study sites were  
138 located within an area of approximately 450 km<sup>2</sup> in the valleys of the Forest of Bowland  
139 which is an upland area situated at 53°58’N, 2°26’W (Figure 1). The mean annual

140 precipitation for the region is 1294mm, mean January temperature is 4.0°C and mean July  
141 temperature is 15.8°C (Met Office, 2016).

142

143 **Figure 1** Location map

144 *Site selection*

145 35 grassland sites were identified where baseline survey data for both quadrat and species list  
146 surveys were available. The data had been collected in the 1980s and 1990s as part of a UK  
147 wide grassland survey (Blackstock *et al.*, 1999). Part of this nationwide survey focused on  
148 mesotrophic lowland (i.e. below the moorland line or lower than approximately 300m above  
149 sea level) grasslands in Lancashire and it is this dataset that forms the baseline for the present  
150 study (Taylor, 1986.). Grasslands in the original surveys were selected using existing Phase 1  
151 habitat survey records and other local information and were chosen because they were  
152 species rich or moderately species rich. The surveys aimed to record sites which were  
153 important for conservation and to compare the botanical detail of sites with similar vegetation  
154 classifications.

155

156 The study incorporated sites from the Forest of Bowland region with contrasting management  
157 regimes including 14 sites which had been managed continuously as hay meadows since the  
158 original surveys were undertaken. Management details for these sites such as earliest cutting  
159 dates, amounts of farmyard manure and dates of removal of grazing stock in the spring can be  
160 linked to their inclusion in agri-environment schemes or designation as protected sites. 10  
161 sites had been managed by grazing (cattle, sheep or a mixture of both). There were also 6  
162 sites which were hay meadows at the time of the first survey but which had seen a change in  
163 management since the first survey was undertaken. The timing of the change is not known for

164 all of the sites but the current management is more intensive and involves either permanent  
165 grazing or cutting for silage rather than hay. The remaining 5 sites are no longer regularly cut  
166 or grazed but, again details of the timings of the change are not known for all of the  
167 grasslands. The sites were located at altitudes varying from 60m to 280m above sea level.  
168 Sites varied in size from 0.2ha to 11.59 ha (Table 1).

169

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

180

181

## 182 **Table 1**

183

### 184 ***Data collection***

185 Repeat surveys (hereafter the second survey) were carried out using the original methods in  
186 the summers of 2012 - 2014. The original surveys (hereafter the first survey) followed Nature  
187 Conservancy Council guidance and involved the placing of 1x1m quadrats in areas deemed to



188 be representative of the main vegetation communities (Smith *et al.*, 1985). The guidance  
189 stated that the quadrats should be placed randomly within each vegetation community  
190 although it was acknowledged that this would not always be possible, particularly in smaller  
191 stands of vegetation. In the meadow communities a random sampling approach would be  
192 straightforward but this might not have been achievable in some of the grazed sites where  
193 species rich flushes and other smaller vegetation stands were surveyed.

194

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

207

208 In addition to the quadrat surveys the first survey involved the compilation of a species list  
209 covering all areas of the site on and within the site boundary (so vegetation in boundary  
210 hedges was included). Site boundaries included hedges, dry stone walls, post and wire fences  
211 and watercourses or ditches. None of these boundaries had been removed or re-positioned

212 since the first surveys were undertaken. The NCC guidelines did not require surveyors to  
213 time the species list survey but there was a requirement to include all of the vegetation  
214 communities on the site.

215

### 216 *Data analysis*

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

229

230 To investigate patterns in community composition revealed by the two survey methods  
231 (quadrat surveys and species list surveys) the quadrat data were first converted from  
232 abundance data to presence/absence data so that they were analysed in the same format as the  
233 species list data. NMDS ordinations for the two survey types were then compared using  
234 Procrustes analysis in the vegan package (Oksanen *et al.*, 2013). Procrustes analysis is used  
235 to investigate the extent to which there is a fit between one ordination or dataset and another

236 and produces a correlation score indicating the extent of the fit based on the distances  
237 between the sampling points or sites. A low score would indicate that there was little  
238 similarity between the two ordinations and *vice versa*. Protest does return *P* values but large  
239 datasets can affect the validity of *P* values and it is recommended that the *r* value is more  
240 useful in interpreting the outcome of the test (Oksanen, *et al.*, 2013).

241

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

245

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

253

254 To assess whether there was any indication of change in functional type in the increased and  
255 decreased species mean values for Ellenberg Indicator Values (EIVs) for the British plants  
256 for light (L), moisture (F), reaction (R) and fertility (N) were calculated for the most  
257 increased and decreased species (Hill *et al.*, 1999). Weightings were not used for the EIVs  
258 because there were no abundance data for the species lists. Ellenberg values can give an  
259 indication of changes in environmental conditions and are useful as a proxy measure when no

260 soil data is available as was the case for these surveys. Calculations of Grime's C-S-R plant  
261 strategy scores using the tool developed by Hunt *et al.* (2004) were also undertaken and  
262 assigned to the most increased and decreased species. The modal C-S-R type was calculated.

263

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

265

## 266 **Results**

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

271

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

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

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

279

280 The NMDS plots for management types show that there is some differentiation between the  
281 survey years (Figs. 3 and 4). In the meadow sites there is some separation along both axes for

282 the quadrat data (Fig. 3a) with less difference between the two years in the species list data  
283 (Fig. 3b). In the grazed sites the differences between the two years are less distinct although  
284 two or three sites in each plot appear to have a different community composition than the  
285 majority of the grazed sites. Figs. 4a and 4b shows that change has taken place in sites which  
286 were managed as hay meadows at the time of the first survey and are now more intensively  
287 managed for silage or by permanent grazing. There is a less distinct pattern in the sites with  
288 little or no management (Figs. 4c and 4d).

289

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

294

295

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

302

303 The two quadrat and species list NMDS ordinations were not found to have a similar  
304 configuration. The Protest permutation test returned an  $r$  value of 0.27 which suggested that

305 there was little correlation between the two ordinations. This result indicates that the two  
306 survey methods revealed contrasting results in terms of community composition.

307

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

318

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

329

330 **Table 2**

331 **Table 3**

332 **Table 4**

333 **Discussion**

334 *Analysis of community composition*

335 Taken as a whole the community composition of the 35 grassland sites had remained similar  
336 between the two survey years based on both the quadrat surveys and the species list surveys.

337 This finding does not reflect the accounts of significant change in other grassland re-  
338 visitation studies (Bennie *et al.*, 2006; Bühler and Roth, 2011). The overall finding of limited  
339 change in the mesotrophic grasslands included in the present study may suggest that they are  
340 more resilient to change than other grassland habitats where the negative impacts of  
341 atmospheric nitrogen deposition and other sources of eutrophication on species richness or  
342 diversity have been greater (Stevens *et al.*, 2010; Van den Berg *et al.*, 2011). Differences in  
343 the responses of grassland habitats to nitrogen deposition have been identified but the results  
344 are influenced by several factors including the baseline nutrient levels of the grasslands in the  
345 study (Maskell, *et al.*, 2010) and the varying effect of reduced or oxidised forms of nitrogen  
346 on the component species of acidic, calcareous or mesotrophic grassland communities (Van  
347 den Berg *et al.*, 2016).

348

349 *Analysis by management type*

350 Analyses of the community composition of the meadow sites in the first and second surveys  
351 indicated that there had been more change identified through the quadrat surveys than by the

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

363

364 There is less clear evidence of change in the grazed sites although two sites from the second  
365 survey in the quadrat plot (Fig. 3c) show some separation from the others. One of these sites  
366 included plants associated with mire communities. The other site was being affected by  
367 encroachment of the woodland adjacent to it and supported woodland as well as grassland  
368 species when the second survey was undertaken. In the species list plot (Fig. 3d) some of the  
369 first survey sites show a degree of separation. Losses of species richness were recorded on  
370 these sites during the second survey which would account for differences in community  
371 composition. It was expected that overall there would be less similarity in the grazed sites due  
372 to the greater variation in terms of topography, hydrology and soil conditions, and in their  
373 management where livestock type, stocking density and timing of grazing could all influence  
374 the vegetation from site to site. However, this does not appear to be the case according to the  
375 data collected for this study. Unlike the meadows only three of the pasture sites are protected  
376 with the others either in lower tier AES schemes, which are less demanding in the



377 management of grasslands for conservation (Natural England, 2013a; 2013b), or not part of  
378 any AES agreement but this lack of a conservation framework for management does not  
379 appear to have led to significant change. The NMDS ordinations are valuable for comparing  
380 community composition across several sites but they are less useful in detecting fine scale  
381 changes which could be occurring within these sites. Hutson (1999) stressed the importance  
382 of scale in patterns of vegetation diversity and demonstrated that local conditions can  
383 influence regional diversity but such influences can be complex and are dependent on the  
384 scale of the study and the type of community.

385

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

402

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

409

#### 410 ***Findings from quadrat and species list surveys***

411 In total more species were recorded in the species list surveys which was expected because  
412 the quadrat survey data is a sub-sample of the whole site. In the changed sites, for example,  
413 some species not found in the main sward had been retained on steeper banks at the edges of  
414 the sites. Some rare and uncommon species were picked up in the species list survey  
415 including *Primula farinosa*, *Platanthera chlorantha*, *Cirsium heterophyllum* and *Genista*  
416 *tinctoria* which have very few local records and are declining at the national level  
417 (Greenwood, 2012; Preston *et al.*, 2002). The comparison of the data resulting from the two  
418 survey methods showed that they had identified differences in terms of community  
419 composition. These differences can be explained by the fact that the species list survey  
420 required that all vegetation communities on the site were included. Features such as streams,  
421 ditches, areas close to a woodland boundary, gateways where there was evidence of  
422 eutrophication or more heavily trampled areas or small areas of acid or calcareous grassland  
423 which were not part of the quadrat survey were present on some sites. It is acknowledged that  
424 the effect of the sampling methods used should also be considered here. Surveyor bias and  
425 subjectivity will have some influence particularly in the compilation of the species lists so

426 care is needed in the interpretation of the results. Ideally monitoring of long-term change  
427 should minimise sampling bias and error and the approach taken by Critchley & Poulton  
428 (1998) illustrates the value of precision and accounting for the optimum monitoring scale for  
429 different species. However, most revisitation studies aim to replicate the methods of the  
430 original survey so there is a trade-off between the value of the long-term data and the  
431 limitations imposed by the original survey design.

432

### 433 *Species losses and gains*

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

443

444 Some losses of positive indicators would be expected given the change to more intensive  
445 management in the former meadow sites but they may also reflect the impact of particular  
446 management prescriptions in sites which are being managed for conservation. For example,  
447 *Ranunculus repens* was recorded on all 35 sites and in most of the quadrats in the second  
448 survey. A study which investigated the control of *R. repens* and *Juncus* species (which also  
449 showed a large increase) found that early summer mowing dates were effective in reducing

450 the abundance of *R. repens* whilst an autumn cut reduced *Juncus* species (Marriott *et al.*,  
451 2003). These cutting dates would not be permitted under AES management prescriptions for  
452 meadow sites.

453

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

471

472 **Conclusion**

473 The community composition of the 35 grassland sites had not seen a marked change at the  
474 regional level over the period of study. This is in contrast to the substantial changes noted in  
475 other re-visitation grassland studies. However important finer scale change was identified and  
476 grassland management had an influence on plant communities. Different survey methods  
477 provided contrasting information about the grassland sites and the combination of quadrat  
478 surveys and species lists can provide valuable information about key vegetation communities  
479 as well as other aspects of the site such as the presence of rare species. There were losses and  
480 gains of positive indicator species as well as changes in negative species but overall there  
481 were more losses than gains. This is a concern and more research is needed to understand  
482 why such losses are occurring particularly in sites which are protected and managed for  
483 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



773 TSM former meadow 6.4 185 3

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

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

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

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**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

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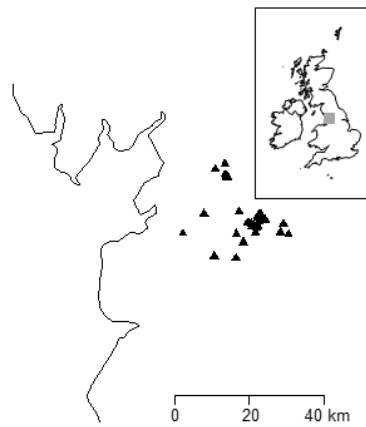
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811 FIGURES

812 **Fig 1.**

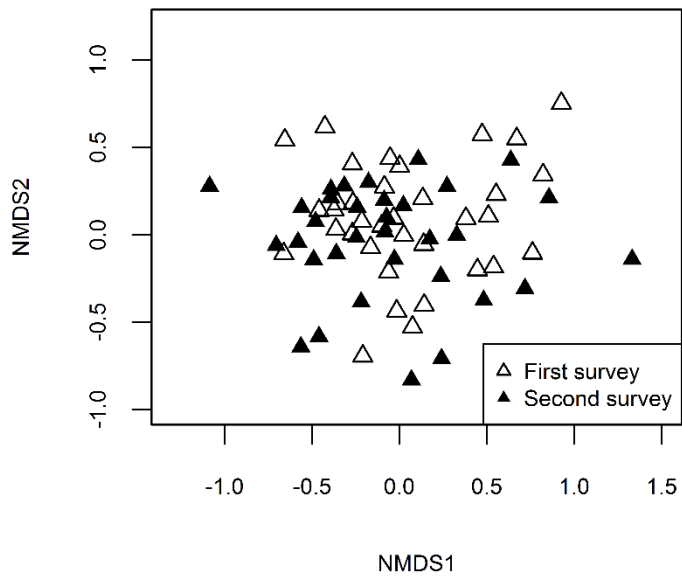
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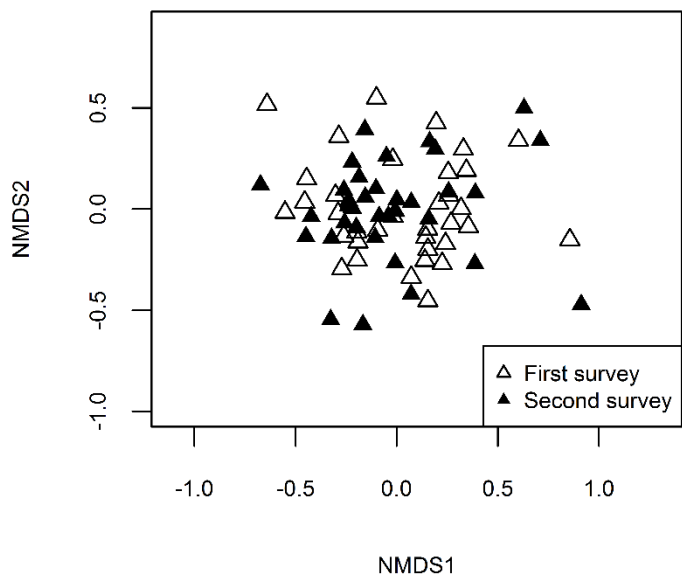
816 **Fig 2a.**



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818 **Fig 2b**

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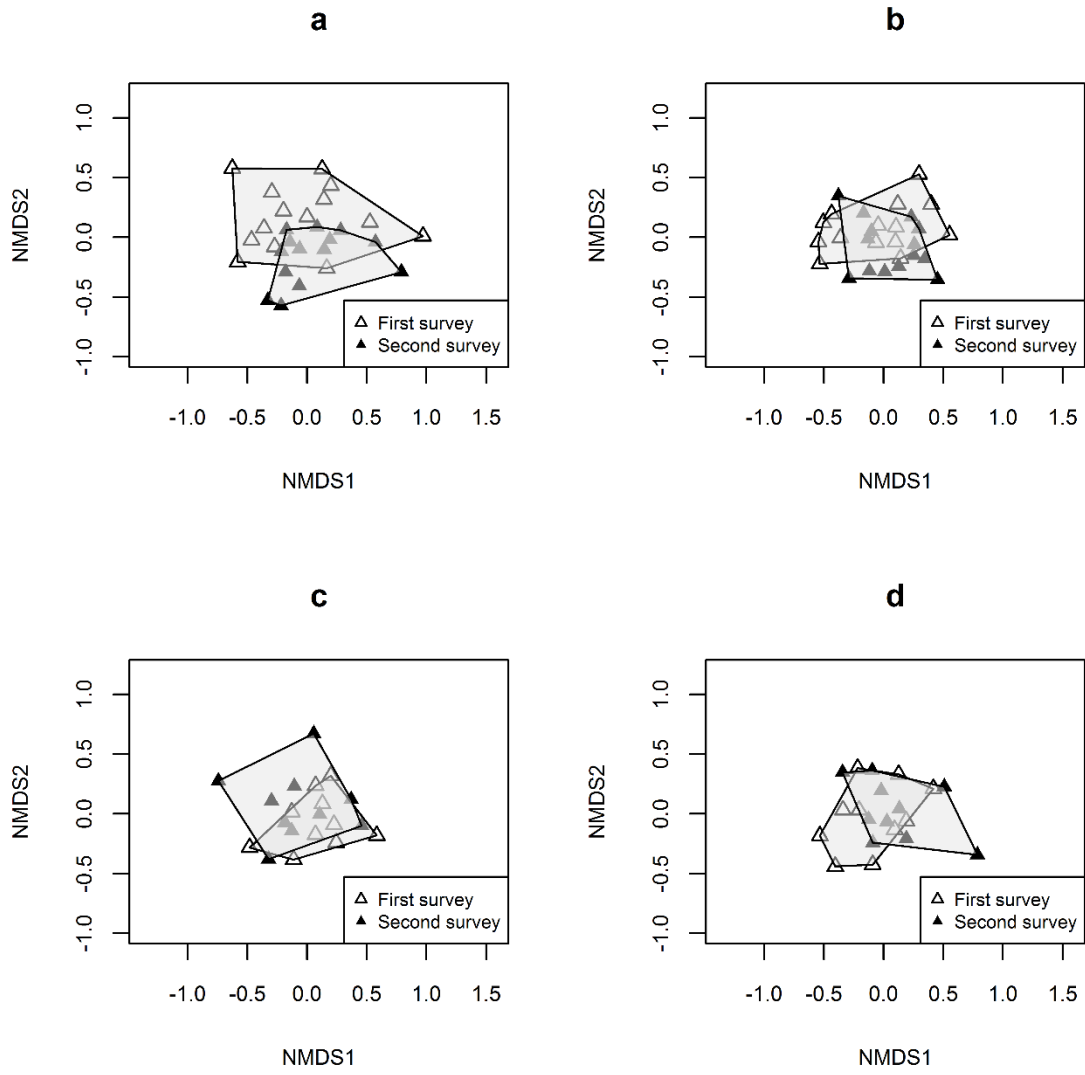


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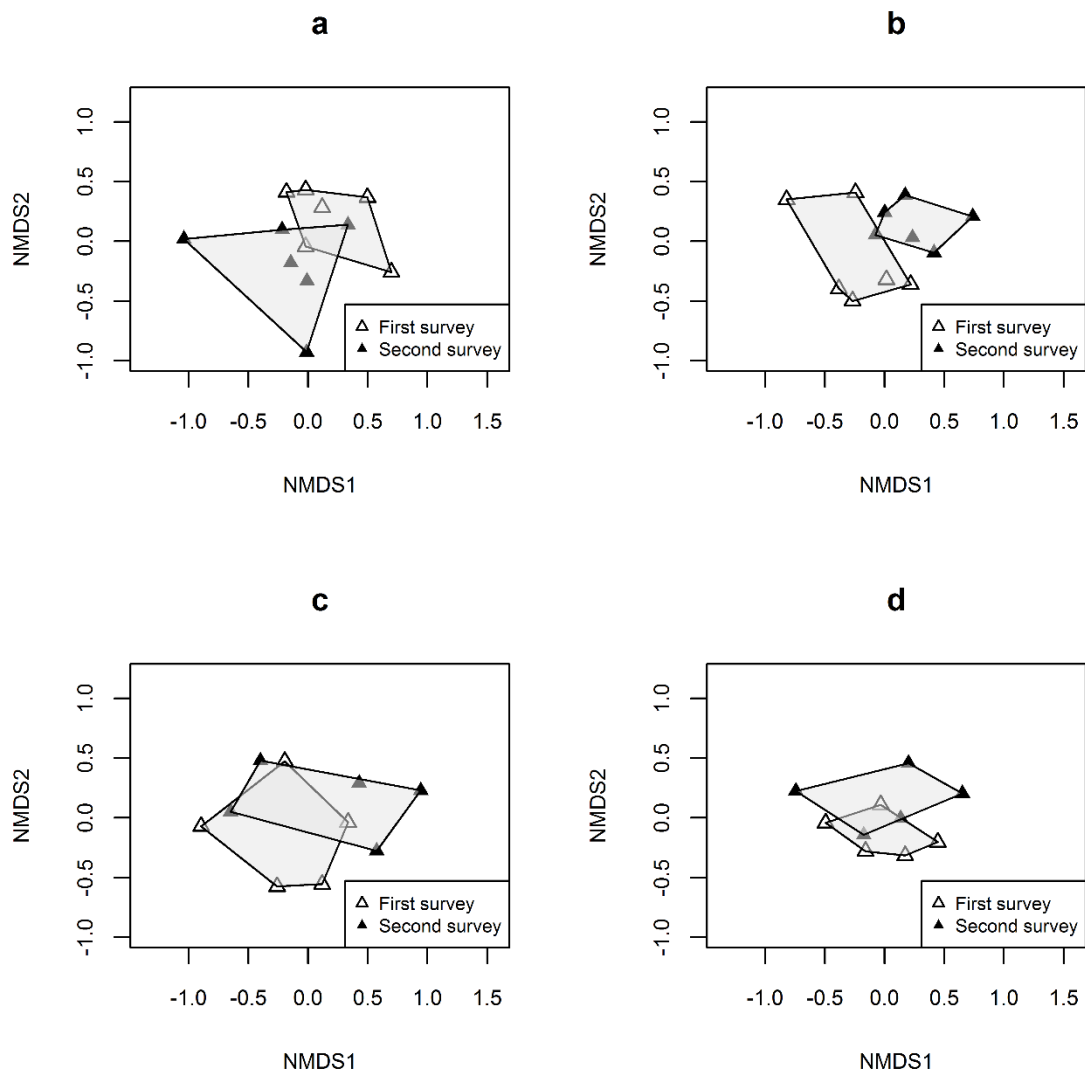
822 **Fig 3**

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**Fig 4**



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832 Appendix 1: Examples of positive indicator species for MG3, MG4 and MG5 grasslands

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834 *Agrimonia eupatoria*

835 *Alchemilla spp.*

836 *Anemone nemorosa*

837 *Betonica officinalis*

838 *Centaurea nigra*

839 *Cirsium heterophyllum*

840 *Conopodium majus*

841 *Euphrasia spp.*

842 *Filipendula ulmaria*

843 *Galium verum,*

844 *Genista tinctoria*

845 *Geranium sylvaticum*

846 *Geum rivale*

847 *Lathyrus linifolius*

848 *Lathyrus pratensis,*

849 *Leontodon spp.*

850 *Lotus corniculatus*  
851 *Oenanthe silaifolia*,  
852 *Persicaria Bistorta*  
853 *Pimpinella saxifrage*  
854 *Polygala spp.*  
855 *Potentilla erecta*  
856 *Poterium sanguisorba*  
857 *Primula veris*,  
858 *Rhinanthus minor*  
859 *Sanguisorba officinalis*  
860 *Serratula tinctoria*,  
861 *Silaum silaus*  
862 *Succisa pratensis*  
863 *Thalictrum Flavum*  
864 *Trollius europaeus*.  
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## 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*  
*Chrysosplenium 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*  
*Hyacinthoides 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*  
*Mercurialis 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 officinale 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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