Three Hagges Woodmeadow Plant Communities 2017-19[1]

Why we monitor the communities. The Trust has been recording the woodmeadow plant communities since 2017 in order to see how the communities established in 2012/13 are evolving and to identify at an early stage any issues with undesirable or over-dominant species. To do this, the abundances of plant species are assessed within a series of fixed quadrats each summer in the areas that were sown to create dry (MG5) and wet (MG4) meadow habitats. The data collected are then analysed using the numerical techniques of ordination and classification which compare quadrats by the species within them: those quadrats most similar in plant composition are grouped closely together in the resulting diagrammatic outputs, whilst those which differ in plant composition are widely separated in the diagrams. In this way, we can judge the degree to which our original MG4 and MG5 communities have remained distinct. The data can also be used to look at how diverse the communities are and how well our "MG4" and "MG5" communities match those which occur more naturally. This report covers the three years 2017, 2018 and 2019.

Establishing the original communities. The woodmeadow at Three Hagges Wood has its origins in the 2012 Queen's Jubilee campaign to plant 6 million trees across the UK. The next year, a 25-acre barley field was leased from Escrick Park Estate on a 35-year lease and 'wet' and 'dry' grassland seed mixes (fine meadow grasses) along with cornfield annuals were sown following glyphosate treatment to establish a stale seed bed, followed by planting of 10,000 tree saplings (Hawthorne 2015 a,b). The area has a long-term arable history so that phosphate levels were high. The meadow seed mixes introduced were loosely based on MG5 ('dry' meadow) and MG4 ('wet' meadow) NVC communities, reflecting the soil conditions across the woodmeadow. The southern end of the woodmeadow had soil removed and was clearly wetter than the northern section. That dividing line is marked today by a clear change in soil level running approximately due west from where the entrance path meets Bodgers Den (northing 439475 on OS map; Figs 1). Species were selected on the matched vigour principle: the most competitive grasses were excluded and the most robust of perennials favoured. In spring 2013, the seed mixes, including a nurse crop of cornfield annuals, were rolled in to avoid disturbing the soil and seedbank (Hawthorne, 2015 a,b).

Recording and monitoring. Initial recording and monitoring of the plant assemblages was rather *ad hoc* along a fixed transect running approximately north-south through the middle of the woodmeadow (Fig. 1) was non-quantitative. In 2017, this approach was replaced by the establishment of fixed, 1-square metre quadrats in the south of the woodmeadow (the original MG4 mix) and in the north, the original MG5 mix (Figs, 1-3, Table 1). The actual boundary between MG4 and MG5 sowing areas is a little uncertain so that the data used in this report excludes some of the original quadrats that straddle the boundary. Preliminary analysis also showed that quadrat MG4_100 was consistently an extreme outlier due its very high abundance of all *Juncus* spp. and confounded interpretations of the data, so that it had to be removed from the analyses.

[1] The data for this May 2020 report were collected by Kat Wotherspoon. All analyses were performed by Dave Raffaelli who also wrote the text with input from Ros Forbes Adam and John Handley. The data files are available from the Trust on request.

Data collection. All quadrats were visited in June and all recording was completed within a single visit. For each species, abundance was estimated as percentage cover on a broadly Domin-like scale (1%, 2%, 5%, 10%, 15%, 25%, etc.), with minor variations. This means that very small differences in abundance may not be real. The data were entered into an Excel spreadsheet to create a table showing the abundance of each species in each of the quadrats, the species-abundance matrix.

Analysis of the data. The table of species abundances for each quadrat can contain a bewildering amount of information: we typically record 35 species from 20 quadrats which means there are 700 data points to stare at! Seeing any meaningful patterns and trends within such large data sets is impossible so plant ecologists turn to the numerical techniques of ordination and classification to simplify the task and extract these patterns for them. These techniques measure the similarity of the plant communities between all pairs of quadrats and the results can be displayed as a picture showing how similar quadrats are to each other: quadrats grouped together in the pictures are more similar in species composition than quadrats widely separated. For ordination analysis this picture is usually a simple two-dimensional plot and for classification it is a branching tree or dendrogram. It is important to repeat ordination analyses using techniques that differ in their underlying basis to make sure that any patterns revealed are consistent and robust and not a product of the particular software. For that reason, we use both DECORANA (Detrended Correspondence Analysis) and NMDS (Non-metric Multidimensional Scaling).

Another way of reducing the complexity of the data set is to distil certain elements, such as diversity, into a single number, the diversity index. or make a plot of the relative abundance of the species so that the dominant and rarer ones can be identified. Diversity indices encapsulate both the number of species present and the abundance of each species. Areas with fewer species or dominated by one or two species have a lower diversity, whereas those with more species and a more even abundance (less dominated by any one species) have a higher diversity.

Technical details of the analyses. Multivariate analysis included ordination by DECORANA (default options selected), Non-metric multidimensional scaling NMDS (on a Bray-Curtis distance matrix, otherwise default options selected), classification by cluster analysis (unweighted average linkage on a Canberra Metric distance matrix) and TWINSPAN (default options selected). Diversity was estimated using Simpson's Inverse (1/D), Shannon-Wiener ($\log_{10}$) and Pielou's Evenness indices. It is important to use a suite of multivariate and univariate techniques to ensure reliable and consistent patterns in the data are revealed. Finally, MAVIS (latest version) was used to estimate the degree of fit of the assemblages to recognised NVC (National Vegetation Classification) MG4 and MG5 communities.

Ordination and classification results. Generally speaking, our MG4 and MG5 quadrats occupy separate parts of the ordination and classification diagrams, confirming that quadrats within the original MG4 area are generally more similar to each other than those from the MG5 area, and *vice-versa*, although there is some grading one into another (Figs. 2-4). The latter is not surprising given the degree of overlap in species composition of recognised MG4 and MG5 communities anyway, but may also reflect uncertainty in the exact seed mix applied in the southern (MG4) part of the woodmeadow (Ros Forbes Adam, pers. comm.).

For the ordination plots (both DECORANA and NMDS), the separation is most convincing for the 2017 and 2019 data, with a less clear picture in 2018. The distinction between MG4 and MG5 is often clearer in the cluster analyses.

Take home message 1. The areas we sowed designated as MG4 and MG5 communities occupy more-or-less separate parts of the ordination plots and branches of the cluster analysis trees, and therefore remain somewhat distinct after 6 years.

TWINSPAN analysis. TWINSPAN, or Two-Way Indicator Species Analysis, is an ordination-based technique that does exactly what it says on the tin: it identifies those species which are more characteristic of particular communities, in our case MG4 and MG5, and presents this as an easy-to-visualise branching tree diagram.

The distinction between MG4 and MG5 areas is confirmed by all three of the TWINSPAN analysis (Fig 4), perhaps not surprising given that the underlying basis of TWINSPAN (Reciprocal Averaging) is similar to the derivation of axis 1 of DECORANA. Good indicator species are those which occur more in one group of quadrats than another, for instance, in all 10 of the MG5 plots and none of the MG4 plots. Note that indicator species are not necessarily those which are most abundant at a site. Given the relatively small number of quadrats analysed for the MG5 (n=10) and MG4 (n=8) areas, identification of indicator species below the first division of the TWINSPAN plots would not be sensible given that fewer and fewer quadrats exist for each subsequent division. Given these constraints, the following very tentative interpretations can be made, based on Figure 4. The lengthy TWINSPAN outputs are not presented here for the sake of clarity but are available on request.

In 2017 and 2018, the MG4 area indicator species were consistently Meadow Foxtail *Alopecurus pratensis,* Sweet Vernal Grass *Anthoxanthum odoratum* and *Juncus* spp. Interestingly, Sweet Vernal Grass was not recorded at all in 2019 from the MG4 quadrats, although the other two species were.

For the MG5 area, indicator species for all three years included the Trefoils *Lotus uliginosus* and *Lotus corniculatus*, Ox-eye Daisy *Leucanthemum vulgare*, Common Yarrow *Achillea millefolium* and Timothy *Phleum pratense.*

Take home message 2: TWINSPAN clearly distinguished the MG4 and MG5 communities. The indicator species revealed by TWINSPAN are consistent with personal observations in 2019, but for a more rigorous TWINSPAN analysis many more quadrats would need to be sampled from both areas.

Measures of diversity. For both the MG4 and MG5 areas, species diversity (Simpson's and Shannon-Wiener indices) increased year-on-year, mainly due to an increase in the Pielou's evenness measure, indication a reduction in dominance by a few species (Tables 2 and 3).

Species rank by abundance changed slightly year-on-year reflecting annual differences in dominant species, for both MG4 and MG5 areas. For the MG4 area (Table 2), Crested Dog Tail *Cynosurus cristatus,* Yorkshire Fog *Holcus lanatus* and Red fescue *Festuca rubra* were most abundant in 2017 and 2018 with Black Medick *Medicago lupulina* in 2018, but in 2019 Knapweed *Centaurea nigra*, Alsike Clover *Trifolium hybridum* and Yellow Rattle *Rhinanthus minor* were the most common.

The MG5 area (Table 3) was, like the MG4 area, dominated by Crested Dog Tail *Cynosurus cristatus*, Yorkshire Fog *Holcus lanatus* and Red fescue *Festuca rubra* in 2017, but also Greater Bird's Foot Trefoil *Lotus uliginosus*. In 2018, Black Medick *Medicago lupulina* and Crested Dog Tail *Cynosurus cristatus* were dominant, and in 2019, Bird's Foot Trefoil *Lotus corniculatus* and Yellow Rattle *Rhinanthus minor*.

The abundance of Knapweed (*Centaurea nigra*) was noticeably high in 2019 in the MG4 area at a mean of c.14%, whilst in 2017 and 2018 it was only c. 10%. In the MG5 area, Knapweed remained at rank 5 for all three years, varying in density from a mean of 8% in 2017, 6% in 2018 and 9% in 2019 (Table 3).

(It has not been possible to carry out any formal statistical analysis of between-year differences in abundance for any of the species because of the Domin-like nature of the data for which no satisfactory data transformation could be found, and because the data are autocorrelated over time due to using fixed quadrats which would demand a repeated ANOVA-type approach for which a non-parametric technique was not available).

Take home message 3. It is clear that there is year-on-year variation in rank abundance of species and that both communities remain floristically diverse, maintaining or even increasing their diversity. There is no evidence of any particular species becoming significantly dominant although there is an impression that knapweed could be increasing in the MG4 area.

MAVIS analysis. Table 4 shows the fit of our MG4 and MG5 data to established NVC descriptions for MG4 and MG5 communities, analysed using the most recent MAVIS application. The fits are around 50-60% for both MG4 and MG5 data sets, with alternative NVC classifications occasionally being a better fit! This variability probably reflects a combination of uncertainties over the seed mix used in some of the MG4 area, the original tailoring of both seed mixes, ecological succession between years as the rank abundance of species changes and between-year variation in exact times of flowering.

Take home message 4: the MG4 and MG5 areas of the woodmeadow have a 50-60% fit with NVC MG4 and MG5 communities, with MG4 being a more variable fit. This degree of fit is probably reasonable given the uncertainty over seed mix in the MG4 area (John Handly, pers.comm.). There is no indication that the MG5 area is becoming less of an NVC MG5 community over the past 3 years.

Overall conclusions. The two areas sampled have remained distinct since the original sowing of the woodmeadow, show a reasonable fit to NVC MG4 and MG5 communities and there is a general increase in species diversity in both community types. However, the fixed quadrats are in two fairly localised areas of the woodmeadow and it is suggested that future surveys of the plant communities employ a larger number of quadrats spread over a wider area.

References

Hawthorn, L. (2015a). The creation of a wood-meadow ecosystem. *Woodland Heritage* 2015: 88-90

Hawthorn, L. (2015b). Three Hagges Wood-Meadow: a model for the potential of wood-meadows for sustaining biodiversity. *Conservation Land Management* Winter 2015: 9-13

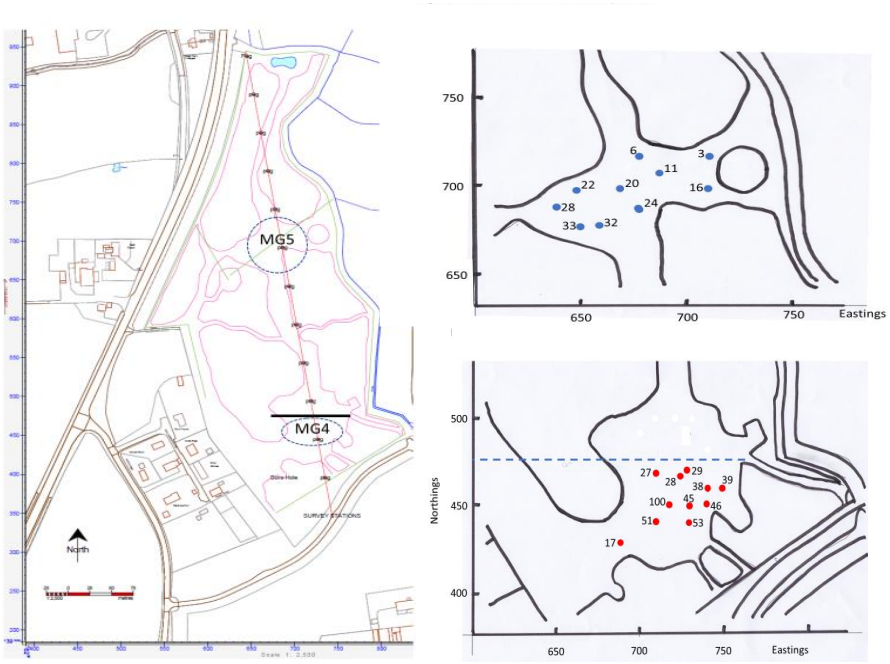
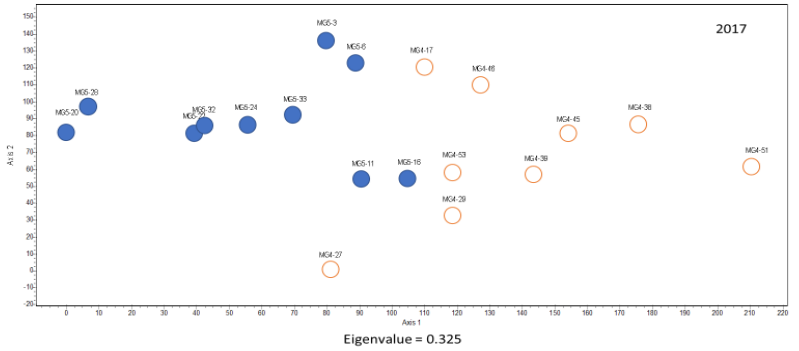
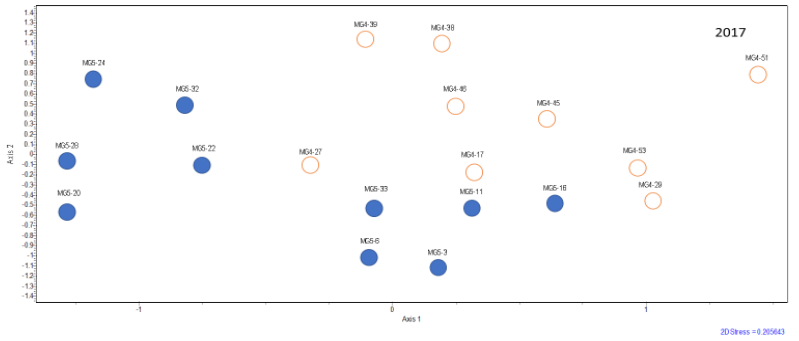


Figure 1. (a) Location of MG4 and MG5 sampling areas and positions of (b) MG5 and (c) MG4 fixed quadrats. The line running north-south in (a) is the original 2014 transect and that running east-west is the boundary between MG5 and MG4 sowing.

Table 1. Co-ordinates of fixed quadrats for plant community analysis. MG4 quadrats 3,4,5,10 and 22 may contain elements of MG5 seeds and those data are not included in this report.

	Northing	Easting			Northing	Easting
MG4-17	439480	462690		MG5-3	439717	462710
MG4-27	439470	462710		MG5-6	439717	462680
MG4-28	439470	462720		MG5-11	439707	462690
MG4-29	439470	462730		MG5-16	439697	462710
MG4-38	439460	462740		MG5-20	439697	462670
MG4-39	439460	462750		MG5-22	439697	462650
MG4-45	439450	462730		MG5-24	439687	462680
MG4-46	439450	462740		MG5-28	439687	462640
MG4-51	439440	462710		MG5-32	439677	462660
MG4-53	439440	462730		MG5-33	439677	462650
MG4-100	439451	462718				





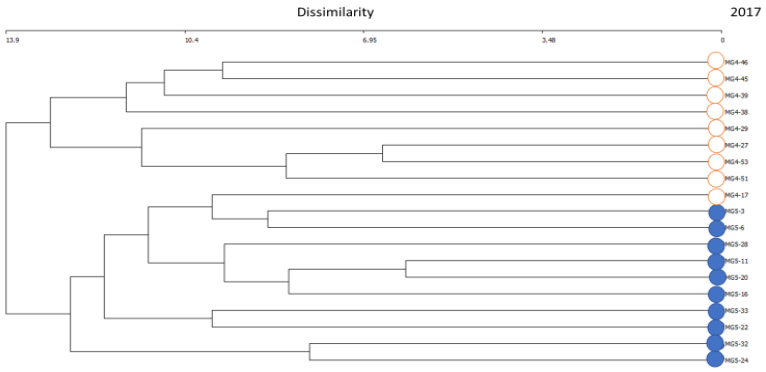
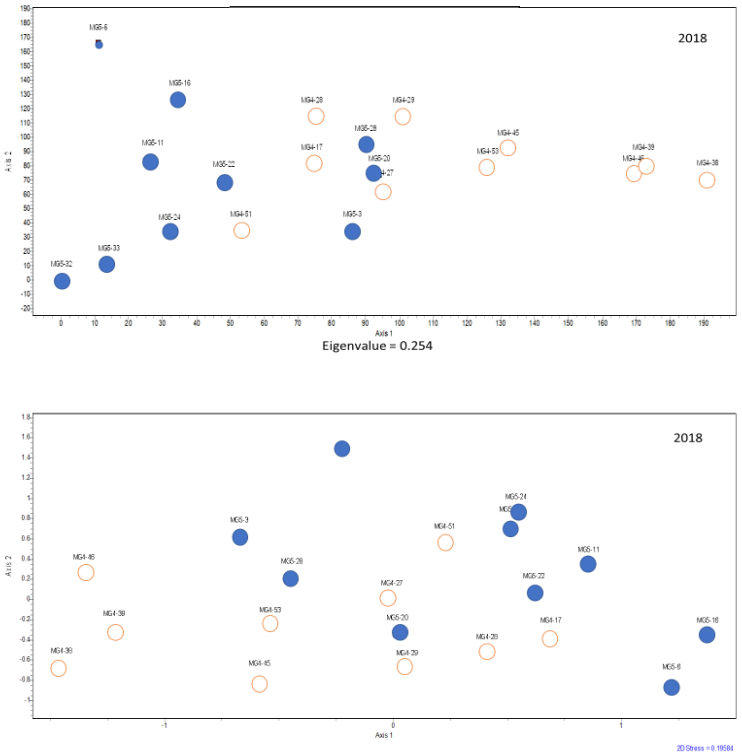


Figure 2. Ordination and classification of 2017 plant community data.
Top, DECORANA; Middle, Multi-dimensional Scaling; Bottom, Cluster analysis.
white circles =MG4, blue circles=MG5



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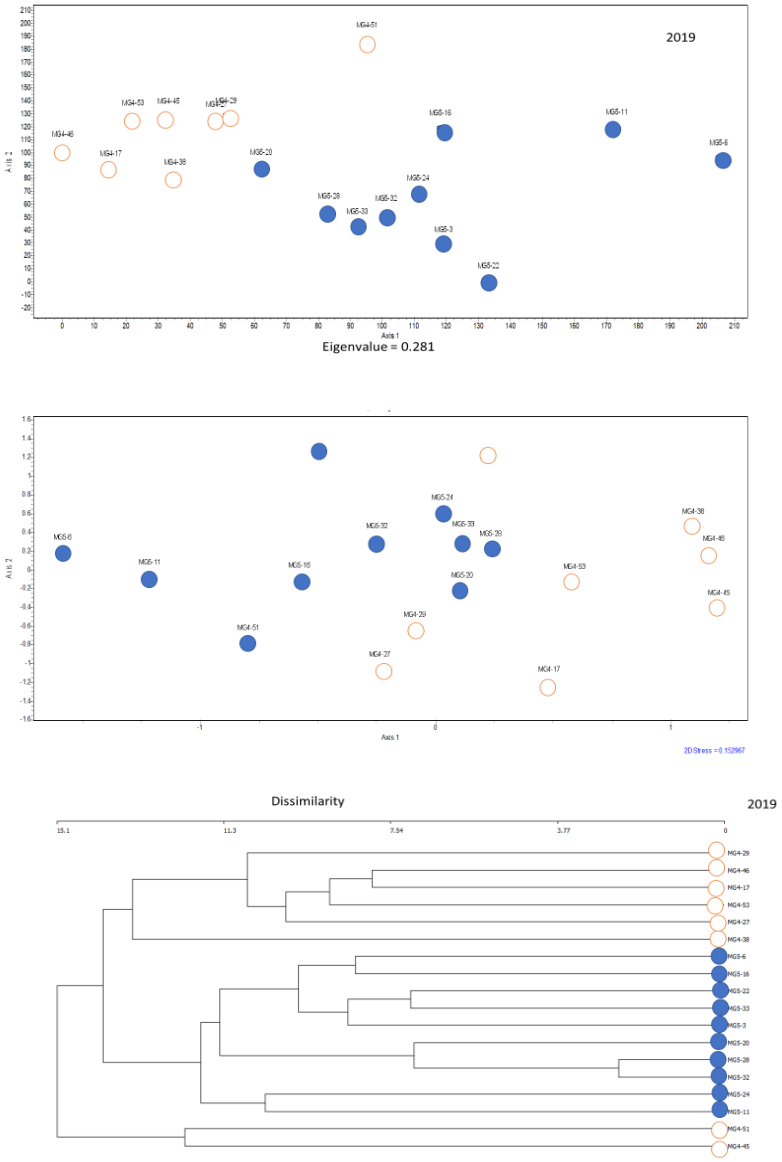

Figure 4. Ordination and classification of 2019 plant community data.
Top, DECORANA; Middle, Multi-dimensional Scaling; Bottom, Cluster analysis.
white circles =MG4, blue circles=MG5

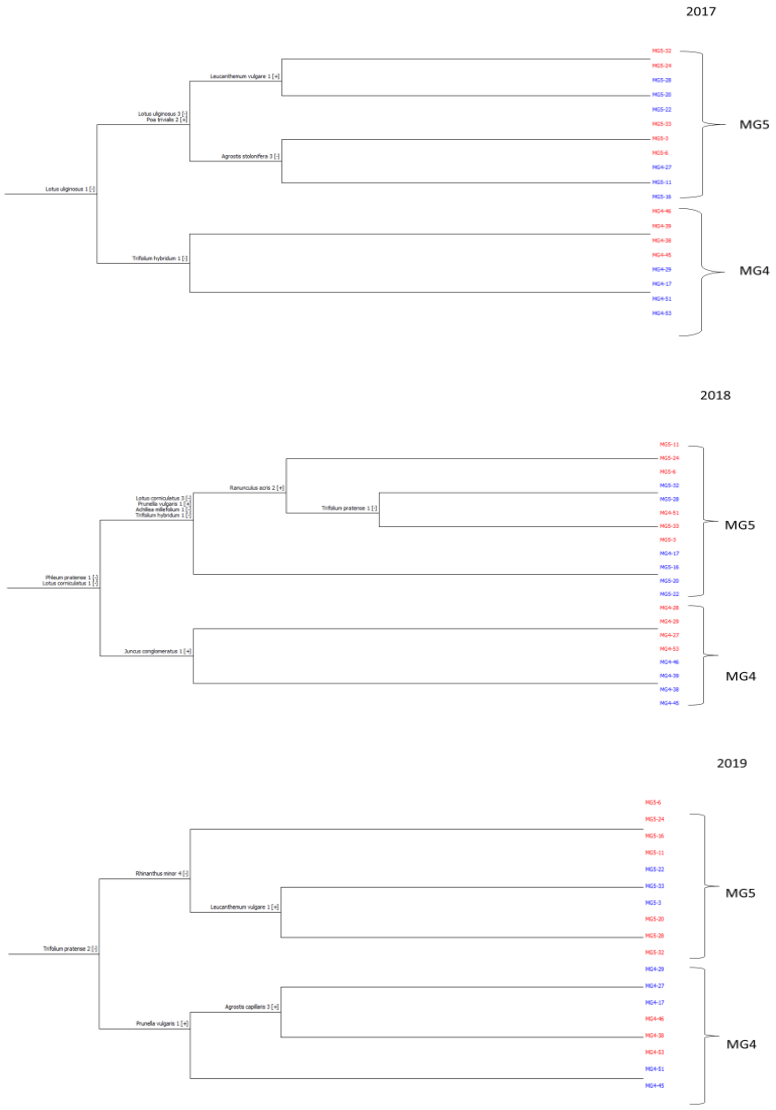

Figure 5. TWINSPAN diagrams for plant community data 2017-2019

Table 2. Rank abundance and diversity measures for MG4 plots.

2017				2018				2019		
	Total	Mean			Total	Mean			Total	Mean
Cynosurus cristatus	200	22.22		*Cynosurus cristatus*	157	15.70		*Centaurea nigra*	112	14.00
Holcus lanatus	165	18.33		*Medicago lupulina*	123	12.30		*Trifoilum hybridum*	84	10.50
Festuca rubra	115	12.78		*Holcus lanatus*	113	11.30		*Rhinanthus minor*	80	10.00
Centaurea nigra	98	10.89		*Festuca rubra*	100	10.00		*Festuca rubra*	74	9.25
Trifolium repens	68	7.56		*Trifolium repens*	80	8.00		*Cynosurus cristatus*	70	8.75
Agrostis capillaris	51	5.67		*Trifoilum hybridum*	80	8.00		*Trifolium dubium*	62	7.75
Agrostis stolonifera	39	4.33		*Centaurea nigra*	70	7.00		*Holcus lanatus*	58	7.25
Trifoilum hybridum	29	3.22		*Agrostis stolonifera*	64	6.40		*Trifolium repens*	49	6.13
Rhinanthus minor	25	2.78		*Agrostis capillaris*	54	5.40		*Agrostis capillaris*	43	5.38
Medicago lupulina	22	2.44		*Plantago lanceolata*	30	3.00		*Agrostis stolonifera*	36	4.50
Poa trivialis	21	2.33		*Anthoxanthum odoratu*	26	2.60		*Alopecurus pratensis*	21	2.63
Lotus corniculatus	20	2.22		*Ranunculus acris*	20	2.00		*Hypochaeris radicata*	17	2.13
Plantago lanceolata	16	1.78		*Alopecurus pratensis*	19	1.90		*Ranunculus acris*	17	2.13
Hypochaeris radicata	11	1.22		*Taraxacum officinale ag*	19	1.90		*Plantago lanceolata*	16	2.00
Anthoxanthum odoratu	9	1.00		*Rhinanthus minor*	17	1.70		*Rumex acetosa*	14	1.75
Alopecurus pratensis	8	0.89		*Lotus corniculatus*	15	1.50		*Lotus corniculatus*	12	1.50
Rumex acetosa	7	0.78		*Hypochaeris radicata*	14	1.40		*Ranunculus bulbosus*	9	1.13
Phleum pratense	5	0.56		*Juncus conglomeratus*	12	1.20		*Juncus conglomeratus*	7	0.88
Calliergon cuspidatum	5	0.56		*Cerastium fontanum*	12	1.20		*Leontodon autumnalis*	7	0.88
Ranunculus acris	4	0.44		*Poa trivialis*	12	1.20		*Taraxacum officinale agg*	6	0.75
Juncus conglomeratus	3	0.33		*Lotus uliginosus*	10	1.00		*Leucanthemum vulgare*	5	0.63
Taraxacum officinale agg	3	0.33		*Rumex acetosa*	10	1.00		*Phleum pratense*	5	0.63
Luzula campestris	2	0.22		*Prunella vulgaris*	9	0.90		*Achillea millefolium*	3	0.38
Achillea millefolium	1	0.11		*Juncus effusus*	6	0.60		*Medicago lupulina*	3	0.38
Juncus effusus	1	0.11		*Luzula campestris*	5	0.50		*Prunella vulgaris*	3	0.38
Cerastium fontanum	1	0.11		*Lychnis flos-cuculi*	4	0.40		*Anthoxanthum odoratur*	2	0.25
Dactylis glomerata	1	0.11		*Trifolium pratense*	4	0.40		*Cerastium fontanum*	2	0.25
Prunella vulgaris	1	0.11		*Juncus articulatus*	3	0.30		*Vicia sativa*	2	0.25
Trifolium pratense	1	0.11		*Lathyrus pratensis*	3	0.30		*Juncus effusus*	1	0.13
				Leontodon autumnalis	3	0.30		*Primula veris*	1	0.13
				Ranunculus repens	3	0.30		*Trifolium pratense*	1	0.13
				Leucanthemum vulgare	2	0.20		*Primula veris*	1	0.13
				Phleum pratense	2	0.20				
				Achillea millefolium	1	0.10				
				Filipendula ulmaria	1	0.10				
Simpson's Inverse	8.495				11.601				13.235	
Shannon-Wiener	2.494				2.884				2.820	
Pielou's Evenness	0.741				0.811				0.821	

Table 3. Rank abundance and diversity measures for MG5 plots.

2017			2018			2019		
	Total	**Mean**		**Total**	**Mean**		**Total**	**Mean**
Cynosurus cristatus	185	18.50	*Medicago lupulina*	180	18.00	*Lotus corniculatus*	133	13.30
Festuca rubra	150	15.00	*Cynosurus cristatus*	160	16.00	*Rhinanthus minor*	111	11.10
Holcus lanatus	135	13.50	*Lotus corniculatus*	80	10.00	*Trifoilum hybridum*	95	9.50
Lotus uliginosus	129	12.90	*Trifolium repens*	76	9.50	*Holcus lanatus*	93	9.30
Centaurea nigra	83	8.30	*Centaurea nigra*	66	6.60	*Centaurea nigra*	92	9.20
Plantago lanceolata	80	8.00	*Holcus lanatus*	63	6.30	*Festuca rubra*	79	7.90
Agrostis capillaris	69	6.90	*Rhinanthus minor*	60	6.67	*Trifolium pratense*	75	7.50
Agrostis stolonifera	58	5.80	*Festuca rubra*	53	5.30	*Cynosurus cristatus*	70	7.00
Vicia cracca	54	6.75	*Trifolium pratense*	53	8.83	*Vicia hirsuta*	64	9.14
Trifolium pratense	43	10.75	*Plantago lanceolata*	52	5.20	*Plantago lanceolata*	62	6.20
Phleum pratense	38	4.22	*Agrostis capillaris*	39	3.90	*Medicago lupulina*	50	12.50
Trifolium repens	29	4.83	*Agrostis stolonifera*	38	3.80	*Agrostis capillaris*	47	4.70
Trifoilum hybridum	25	6.25	*Poa trivialis*	38	4.22	*Trifolium dubium*	45	7.50
Rumex acetosa	13	1.44	*Phleum pratense*	26	3.25	*Agrostis stolonifera*	33	3.30
Poa trivialis	10	1.67	*Trifoilum hybridum*	26	5.20	*Ranunculus acris*	23	2.56
Medicago lupulina	9	1.80	*Ranunculus acris*	20	2.22	*Phleum pratense*	20	2.50
Leucanthemum vulgar	8	1.33	*Rumex acetosa*	16	1.60	*Rumex acetosa*	16	2.00
Achillea millefolium	6	1.50	*Lolium perenne*	15	3.75	*Achillea millefolium*	15	3.75
Calliergon cuspidatum	6	1.50	*Achillea millefolium*	11	2.20	*Trifolium repens*	15	5.00
Ranunculus acris	4	1.00	*Prunella vulgaris*	9	3.00	*Lolium perenne*	7	3.50
Hypochaeris radicata	3	1.50	*Vicia hirsuta*	9	1.80	*Leontodon autumnalis*	4	1.00
Alopecurus pratensis	2	1.00	*Hypochaeris radicata*	8	2.67	*Leucanthemum vulgar*	4	1.00
Lolium perenne	2	2.00	*Leucanthemum vulgare*	8	2.00	*Vicia sativa*	4	1.33
Prunella vulgaris	2	1.00	*Cerastium fontanum*	5	5.00	*Prunella vulgaris*	3	1.50
Galium verum	1	1.00	*Anthoxanthum odoratu*	3	1.00	*Hypochaeris radicata*	1	1.00
			Alopecurus pratensis	2	2.00			
Simpson's Inverse	10.798			12.772			14.907	
Shannon Weiner	2.609			2.823			2.848	
Pielou's Evenness	0.810			0.856			0.885	

Table 4. MAVIS fit of Three Hagges Woodmeadow MG4 and MG5 plant communities 2017-2019.

(a) MG4 quadrats

2017	2018	2019
NVC: MG5c 60.08	**NVC: MG4b 61.35**	NVC: MG5a 58.64
NVC: MG5 58.48	NVC: MG6d 60.37	NVC: MG5c 58.08
NVC: MG4b 58.44	**NVC: MG4 58.99**	NVC: MG5 58.01
NVC: MG5a 58.40	NVC: MG5c 58.95	NVC: MG5b 55.34
NVC: MG6b 57.29	NVC: MG8d 58.54	**NVC: MG4b 55.17**
NVC: MG8d 56.74	NVC: MG5a 58.03	**NVC: MG4a 55.01**
NVC: MG5b 56.43	**NVC: MG4a 57.82**	**NVC: MG4 54.05**
NVC: MG4a 56.24	**NVC: MG4v2 57.72**	**NVC: MG4v2 53.00**
NVC: MG6d 56.12	NVC: MG5 56.59	NVC: MG8d 52.54
NVC: MG4v2 55.02	NVC: MG8 53.22	NVC: MG6d 52.11

(b) MG5 quadrats

2017	2018	2019
NVC: MG4b 52.28	**NVC: MG5a 58.53**	**NVC: MG5a 55.16**
NVC: MG4v2 50.85	NVC: MG4b 58.15	**NVC: MG5 54.40**
NVC: MG4a 50.66	NVC: MG6b 58.04	**NVC: MG5c 53.20**
NVC: MG5a 50.51	NVC: MG4a 56.78	**NVC: MG5b 52.26**
NVC: MG5b 50.00	**NVC: MG5 56.27**	NVC: MG4a 50.83
NVC: MG5 49.86	NVC: MG8d 55.56	NVC: MG4b 49.98
NVC: MG6b 49.24	NVC: MG4v2 55.12	NVC: MG6b 49.98
NVC: MG6d 47.88	**NVC: MG5c 54.99**	NVC: MG4 48.67
NVC: MG4c 47.53	**NVC: MG5b 53.95**	NVC: MG8d 47.48
NVC: MG6a 47.28	NVC: MG6d 53.78	NVC: MG6 47.12

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