Environment and Rural Affairs Monitoring & Modelling Programme (ERAMMP)

ERAMMP Report-30: Analysis of National Monitoring Data in Wales for the State of Natural Resources Report 2020

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Contents

Annexes referred to in this report can be found in the separate Technical Annex document: Report-30TA1

Abbreviations and some of the technical terms used in this report are expanded on in the project glossary: https://erammp.wales/en/glossary (English) and https://erammp.cymru/geirfa (Welsh)

1 Summary

The Glastir Monitoring and Evaluation Programme (GMEP, https://gmep.wales/) was at the forefront of the ecosystem approach to monitoring the impact of Pillar II schemes across the European Union - as recognised by the European Commission's Monitoring and Evaluation Help Desk. GMEP also recruited a large sample of counterfactual "wider Wales" sites, thus enabling additional all Wales reporting. GMEP and other assimilated data represents a significant source of robust, timely and spatially relevant evidence which can contribute to SoNaRR. **To facilitate use of GMEP data in SoNaRR, we present new analyses of national monitoring data** which has been co-developed with SoNaRR technical leads at Natural Resources Wales (NRW). Key findings for four SoNaRR themes are as follows:

Semi-natural grassland (SNG)

Improvements

Increasing: Species richness of positive indicator flora on acid grassland since 2007.

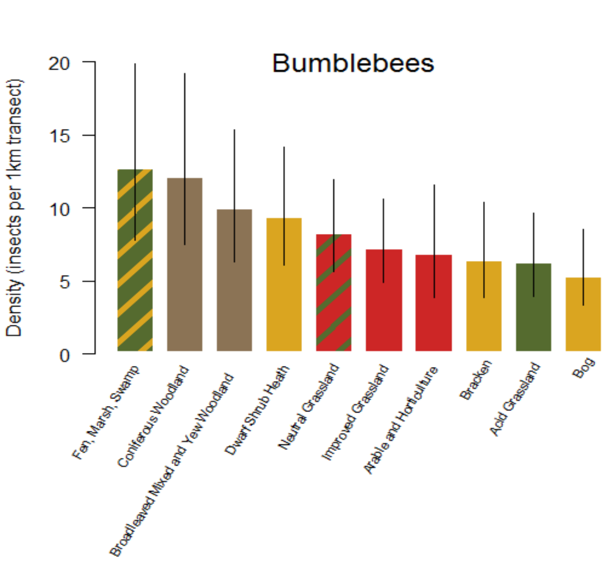

Figure 1.1. *Bumblebee density estimates across broad habitat types. Error bars represent 95% confidence intervals*

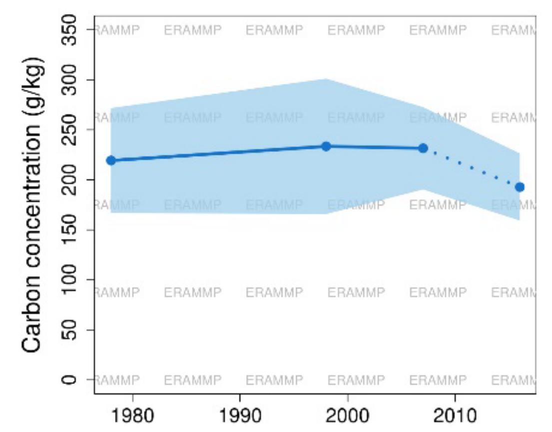

Figure 1.2. *Topsoil carbon concentration over time in acid grassland in Wales. This trend contributes to significant declines across habitats in upland Wales*

High: Marshy grassland supports high butterfly and bumblebee counts **(Fig. 1.1)**.

Could improve: 20% of vegetation plots in Wales are on neutral grassland, but only <1% are on semi-natural neutral grassland.

Decreasing: Topsoil carbon declined in the uplands since 2007. This includes acid grassland **(Fig. 1.2)**.

Woodland

Improvements

Increasing: Richness of ancient woodland indicator species in broadleaved woodlands.

High: Woodlands support high numbers of many pollinator groups **(e.g. Fig. 1.1)**.

Could improve: Dormouse indicators are rare in broadleaved woodland.

Note: Non-native ground flora are more frequent in coniferous than broadleaved woodlands. The opposite is true of butterfly food plant and nectar plant species.

Enclosed Farmland

Improvements

Increasing: Species-richness of ground flora along hedgerows.
Decreasing: Soil phosphorus and bulk density on improved grassland, indicating an improvement in soil health.

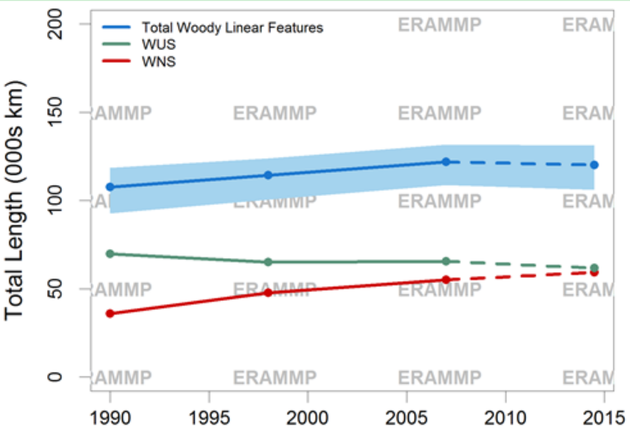

Figure 1.3. *Length of woody linear features in Wales over time. WUS=Woody Unnatural Shape (e.g. trimmed hedge). WNS=Woody Natural Shape.*

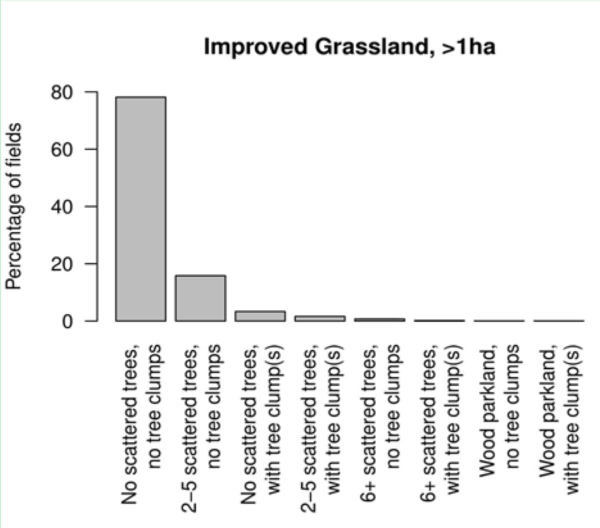

Figure 1.4. *Percentage of large (>1ha) improved grassland fields in categories with/without trees or clumps of trees.*

Stable: Length of woody linear features in Wales' wider countryside **(Fig. 1.3)**.

Could improve: 74-90% of farmed grassland fields contain no trees **(Fig. 1.4)**.

Mountain, moor & heath (MMH)

Improvements

Increasing: Overall plant species-richness on heath habitat **(Fig. 1.5)**.
Increasing: Species richness of positive indicator flora on bog.

Decreasing: Recent topsoil carbon declines in the uplands include MMH.

Low: Pollinator counts are low, except for bumblebees on heath **(Fig. 1.1)**.

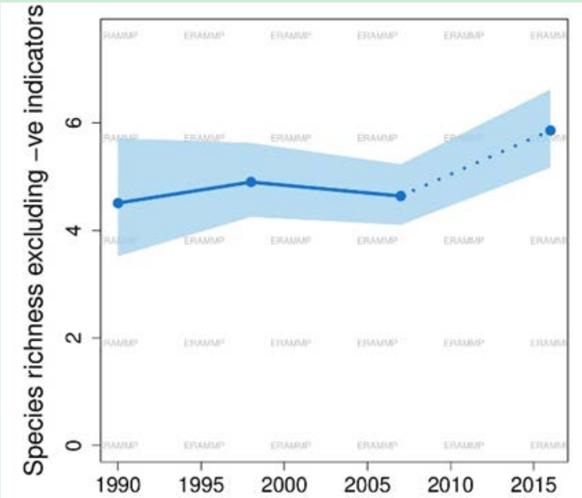

Figure 1.5. *Species richness, excluding negative indicators, of heath over time.*

This work was commissioned by NRW, co-developed by NRW and UKCEH, and jointly funded by Welsh Government and NRW (NRW contribution ~20%). **The goal is to facilitate use of data and findings from Welsh Government's national monitoring programmes in SoNaRR, both now and into the future.** ERAMMP field survey is scheduled between 2020 and 2022, including revisits to the majority of GMEP survey squares. This will provide further evidence on state and trends in natural resources in Wales' wider countryside.

2 Introduction

The Glastir Monitoring and Evaluation Programme (GMEP, https://gmep.wales/) was an ecosystem monitoring and evaluation programme commissioned by Welsh Government from 2013-2016 (Emmett and the GMEP team 2017). It monitored soils, freshwaters, habitats, plants, birds, pollinators and more across 300 1km squares in Wales. It has been recognised as at the forefront of the ecosystem approach to monitoring the impact of Pillar II schemes across the European Union - as recognised by the European Commission's Monitoring and Evaluation Help Desk.

Welsh Government's current Environment and Rural Affairs Monitoring and Modelling Programme (ERAMMP, https://erammp.wales) incorporates revisits to 240 of 300 GMEP squares to take exact repeat measurements of most aspects of the GMEP survey. This will capitalise on abundant baseline information provided by GMEP, and determine recent trends in the environment across Wales. Thanks to continuity between GMEP and the GB-wide Countryside Survey (CS; Smart et al. 2009, Emmett et al. 2010b, Wood et al. 2017), it is already possible to produce trends in soil properties and vegetation condition across Wales up to 2016. Such trends, in some cases extending back to 1978, are presented in the GMEP final report to Welsh Government (Emmett and the GMEP team 2017) as well as ERAMMP Report 20 - *Re-analysis of data for SoNaRR*[1] (with analyses tailored to SoNaRR themes; Maskell et al. 2019a). More information is included in Annex 1 of this report.

> *CS, GMEP and ERAMMP produce high quality data on natural resources in Wales' wider countryside. These data have potential to inform SoNaRR, as a complement to data from other monitoring efforts*

CS, GMEP and ERAMMP produce a substantial quantity of high quality data on natural resources in Wales' wider countryside. These data have potential to inform SoNaRR[2], as a complement to data from other monitoring efforts such as the National Forest Inventory (Forest Research 2020) and the National Soils Inventory (Cranfield University 2020). **This report presents new analyses of national monitoring data collected under CS and GMEP. These analyses have been co-developed with NRW SoNaRR technical leads in order to maximise their accessibility and relevance to SoNaRR themes.** We present cross-cutting analyses of soil properties and pollinator abundance (Section 3), followed by tailored analyses of vegetation condition, species richness and other data (e.g. the density of individual trees) across four SoNaRR themes: Enclosed farmland; semi-natural grassland; mountain, moor and heath and woodland (Sections 3.3-7). Annex 2 of this report presents new GMEP analysis of the extent of broad and priority habitats.

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[1] https://erammp.wales/sites/default/files/ERAMMP%20Rpt%2020%20SoNaRR%20v1.0.pdf

[2] State of Natural Resources Reporting (SoNaRR) is legally delegated to NRW as set out in the Environment (Wales) Act 2016 (National Assembly for Wales 2016). The first SoNaRR report (https://naturalresources.wales/evidence-and-data/research-and-reports/the-state-of-natural-resources-report-assessment-of-the-sustainable-management-of-natural-resources/?lang=en), published in 2016, summarised state, condition and trends of natural resources across eight ecosystems: Mountains, moors and heaths; semi-natural grassland; enclosed farmland; woodland; freshwater; urban environments; coastal margins and marine. It also covered evidence gaps, resilience, sustainability and long-term social, cultural, environmental and economic well-being.

3 Analyses Across all SoNaRR Themes

3.1 Trends: Soil properties

The Glastir Monitoring and Evaluation Programme (GMEP) final report presented analysis of trends in soil properties of woodland, improved land and "habitat" land (all non-woodland, non-improved land; Emmett and the GMEP team 2017) as requested by the GMEP Steering Group. Further analysis of soil properties, breaking down the "habitat" category into semi-natural grassland (SNG) and mountain, moor & heath (MMH), was provided in ERAMMP Report 20: *Re-analysis of data for SoNaRR* (Maskell et al. 2019a). It was agreed that further breakdown of soil properties was desirable across the SoNaRR themes, where adequate data exist. Furthermore, it was requested that data on soil bulk density be included.

Here we present a more comprehensive set of soil property trend analyses, including bulk density, linking back to data from Countryside Survey (CS, Emmett et al. 2010a). We present trends for a total of 10 categories: three categories used in the GMEP final report, an updated MMH category (not including lowland fen, marsh and swamp), and six new categories (arable, improved grassland, semi-improved grassland, acid grassland, broadleaved woodland and coniferous woodland. Table 3.1.1). We also present a more detailed breakdown of bulk density across habitat types. Analysis of trends in topsoil mesofauna is not presented as trends cannot be broken down any further. Please refer to previous reports for trends, and refer to George et al. (2017, 2019) for analysis of soil fauna across habitat types.

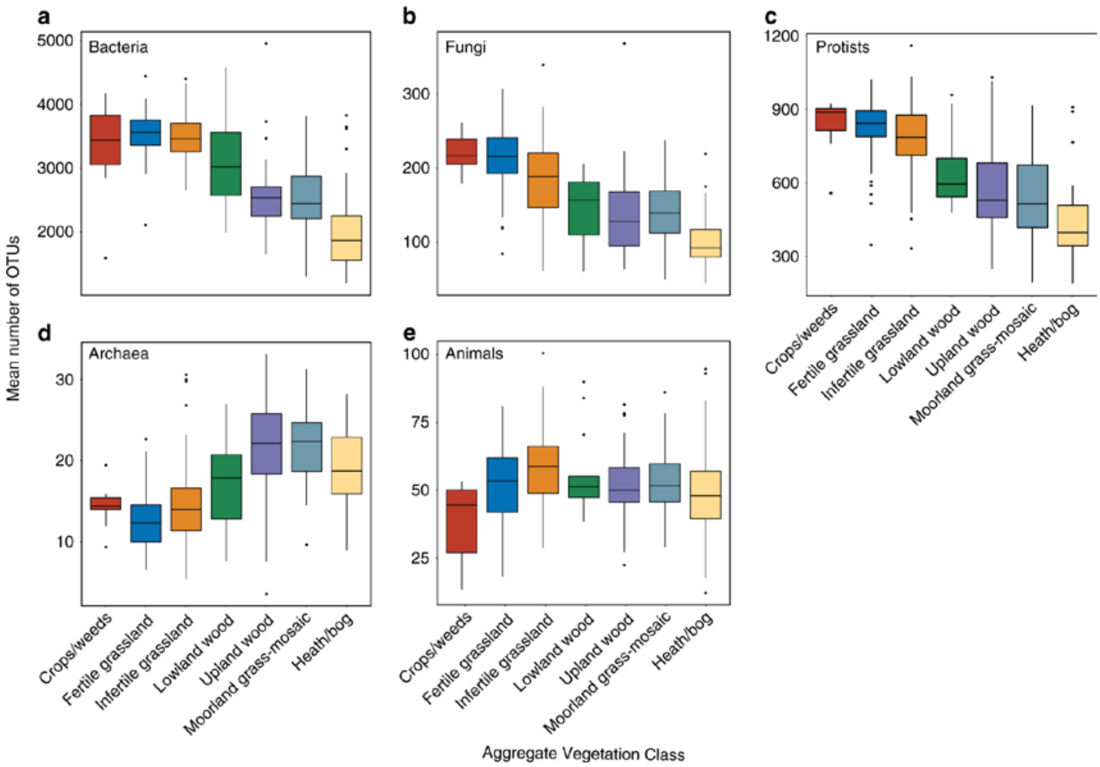


Figure 3.1.1. Boxplots of operational taxonomic unit (OTU) richness for each organismal group. Richness of **a** bacteria; **b** fungi; **c** protists; **d** archaea; **e** animals are plotted against Aggregate Vegetation Class ordered from most (crops/weeds) to least (heath/bog) productive. Boxes are bounded on the first and third quartiles; horizontal lines denote medians. Black dots are outliers beyond the whiskers, which denote 1.5× the interquartile range. Reproduced from George et al. (2019).

3.1.1 Methods

In brief, five intact soil cores (0-15cm) are collected from the corners of the five permanent vegetation ('X') plots within each survey square. Cores are returned to the laboratory for a wide range of physical, chemical and biological properties. Dried, ground samples are archived as are an intact frozen core for potential future pollutant and biological analysis. All soil properties selected are indicators which were proposed and tested by the UK Soil Indicators Consortium for specific functions including environmental interactions which include hydrological filtering by soils, habitat support and carbon gas exchanges with the atmosphere. As the sampling and analytical methodology used for topsoil in GMEP is identical to that used in Countryside Survey these datasets can be combined to look for long-term national trends. For more information on GMEP square selection and soil sampling and analysis methodology, see the GMEP reports and appendices https://gmep.wales/.

Trend analysis was conducted for carbon concentration (g/kg), pH, total nitrogen (%), Olsen phosphorus (improved habitats only; mg/kg), and the bulk density of the fine earth fraction of 0-15cm topsoil (g cm^{-3}) in 10 categories: three categories used in the GMEP final report, an updated MMH category (not including lowland fen, marsh and swamp), and six new categories (arable, improved grassland, semi-improved grassland, acid grassland, broadleaved woodland and coniferous woodland). We extracted soil samples for each category based on broad habitat, cover of *Lolium* and *Trifolium repens* (as indicators of improved grassland) and overlap with the NRW upland boundary (details outlined in Table 3.1-1). Some soil properties were only available in recent time-periods; for example bulk density measurements were only available in 2007 and GMEP 2013-2016 (hereafter referred to as GMEP 2016).

Trends analysis was done using linear mixed-effects models fitted in the *R* package *nlme* (Pinheiro et al. 2019, R Core Team 2019), with a fixed-effect of year and a correlation structure to account for repeated measures. To test for significant differences over time, we used *t*-tests to see if the parameters for 1978, 1998 and 2007 differed significantly from 2016 (with 2016 set as the reference level, or intercept, in the model).

3.1.2 Results

Results are shown in Tables 3.1.2-11 and Figures 3.1.1-5. *P*-values for each variable are for comparisons with 2016. For example, Table 2 shows a decrease in carbon on habitat land from 159.64 in 2007 to 132.48 in 2016, with $P = 0.02$ indicating significance, where (0.05 is considered the significance threshold).

Table 3.1-1 Lookup table between broad habitats and reporting categories for soils analysis in the GMEP final report, ERAMMP Report 20 and further analysis in this report. N/A = not represented, with insufficient data for analysis.

Broad Habitat	GMEP Final Report	ERAMMP Year 1 Report	Further Breakdown (This Report)
Arable & Horticultural	Improved land	Enclosed farmland	Arable
Improved Grassland	Improved land	Enclosed farmland	Improved grassland
Neutral grassland (>25% *Lolium + Trifolium repens* cover)	Improved land	Enclosed farmland	Improved grassland
Neutral grassland (<25% *Lolium + Trifolium repens* cover)	Habitat	Semi-natural grassland	Semi-improved grassland
Calcareous grassland	Habitat	Semi-natural grassland	N/A
Acid grassland	Habitat	Semi-natural grassland	Acid grassland
Dwarf shrub heath	Habitat	Mountain, moor & heath	Mountain, moor & heath
Bog	Habitat	Mountain, moor & heath	Mountain, moor & heath
Bracken	Habitat	Mountain, moor & heath	Mountain, moor & heath
Fen, marsh & swamp	Habitat	Mountain, moor & heath	Only in MMH if within NRW upland boundary
Montane	Habitat	Mountain, moor & heath	Mountain, moor & heath
Inland rock	Habitat	Mountain, moor & heath	Mountain, moor & heath
Broadleaved, mixed & yew woodland	Woodland	Woodland	Broadleaved woodland
Coniferous woodland	Woodland	Woodland	Coniferous woodland

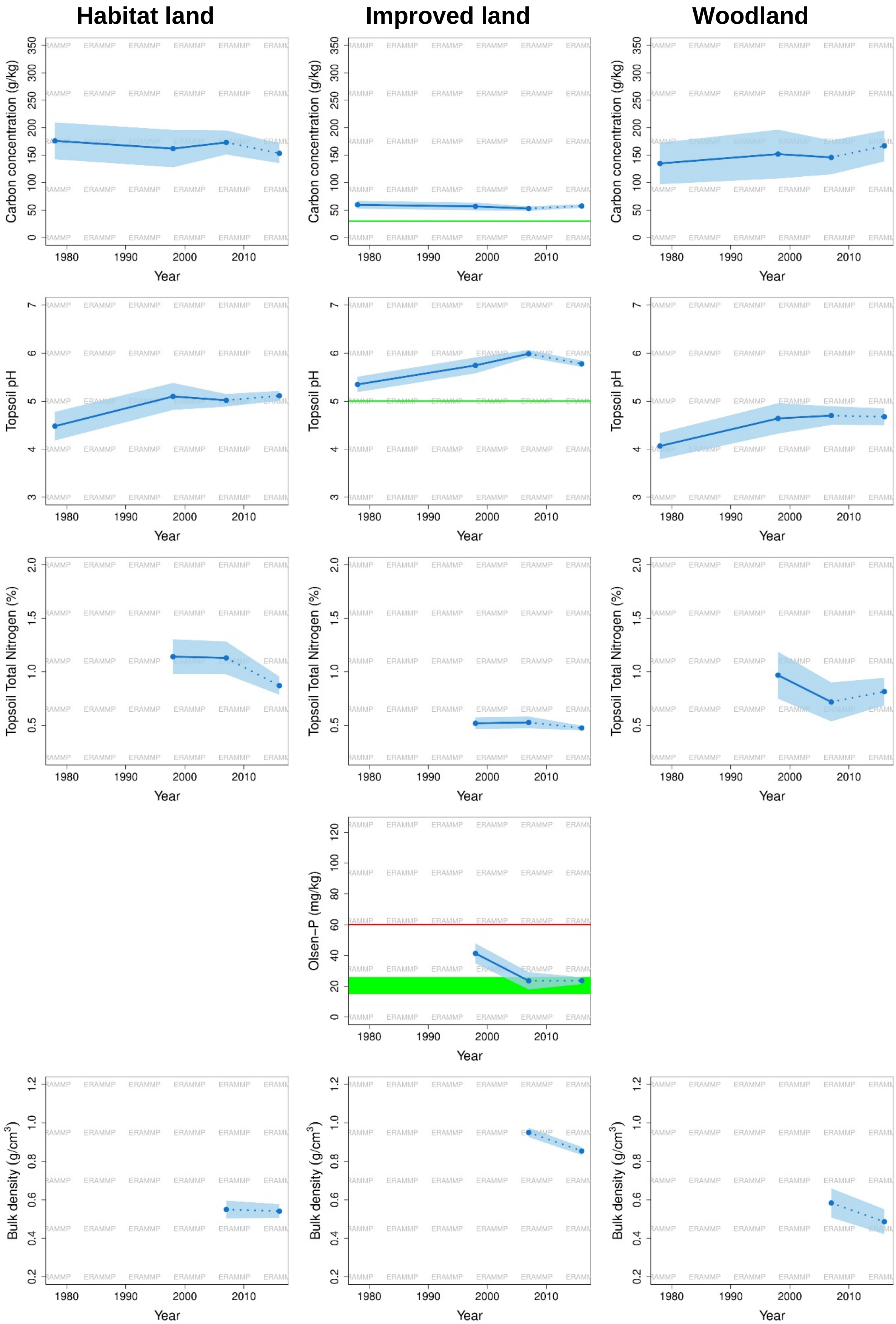


Figure 3.1.2. Trends in soil properties across three reporting categories from the GMEP final report. Blue dots and lines represent estimates, light blue areas represent 95% confidence intervals. Red lines indicate thresholds not to exceed. Green lines indicate thresholds not to fall below.

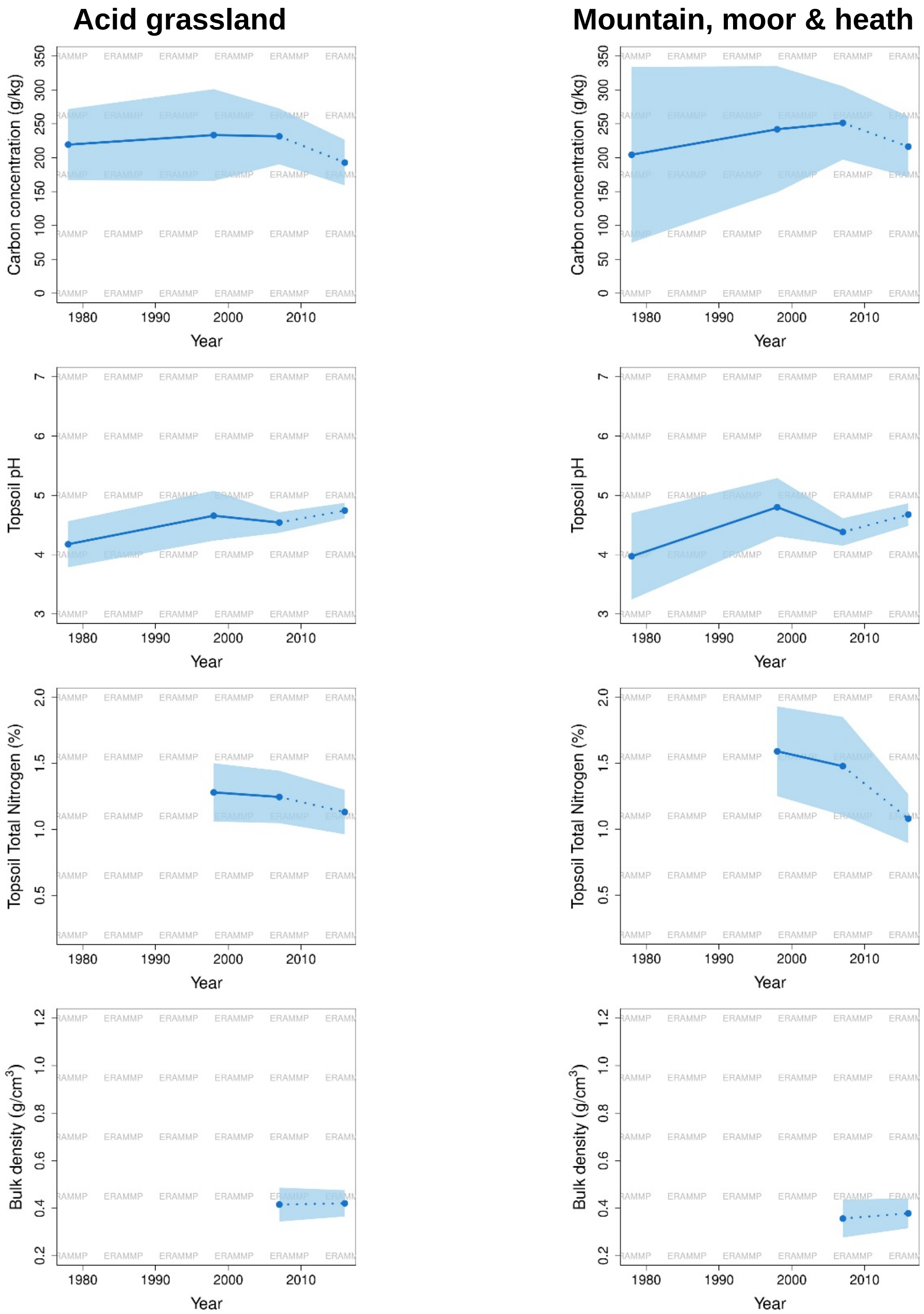


Figure 3.1.3. Trends in soil properties across acid grassland and mountain, moor & heath. Blue dots and lines represent estimates, light blue areas represent 95% confidence intervals

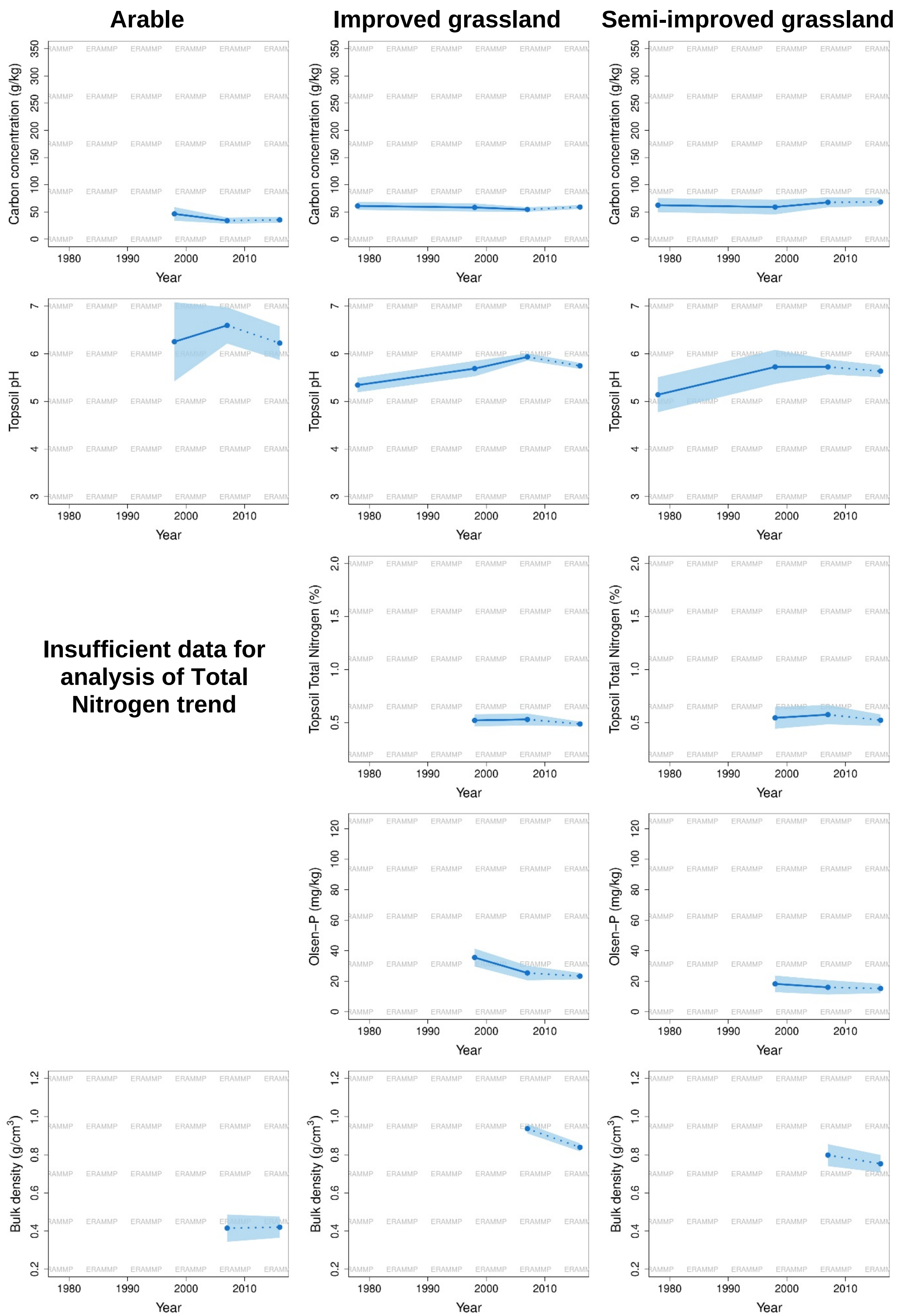


Figure 3.1.4. Trends in soil properties across arable, improved and semi-improved grassland. Blue dots and lines represent estimates, light blue areas represent 95% confidence intervals. For Arable land, there were insufficient data in 1978 for all analyses, and 2007 for Olsen-P and total nitrogen.

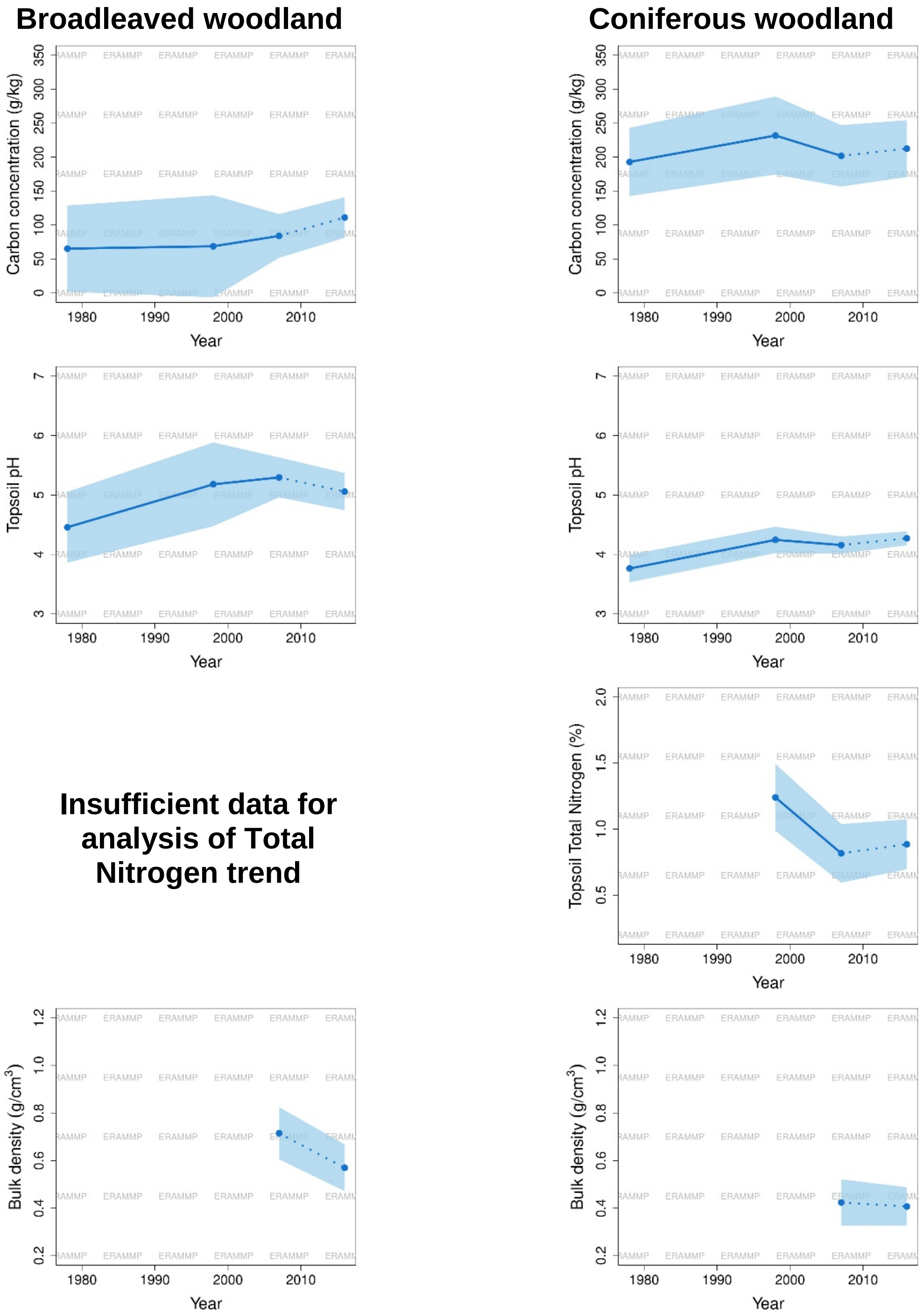


Figure 3.1.5. Trends in soil properties across arable, improved and semi-improved grassland. Blue dots and lines represent estimates, light blue areas represent 95% confidence intervals. For broadleaved woodland, there were insufficient data for total nitrogen trends.

Table 3.1.2. *Trends in soil properties on* ***habitat land****. Estimates of each property in each year are from linear mixed-effects models.* P*-values lower than 0.05 (bold text) indicate years where estimates are significantly different from 2016. The number of relevant soil samples in each year is also shown. "↔" represents non-significance in a trend, indicating stability and/or low sample size.*

Variable	Year	Estimate	*P*-value vs. 2016	n samples	Long-term trend	Short-term trend
Carbon concentration (g/kg)	1978	156.39	0.14	25	↔	↓
	1998	146.55	0.41	31		
	2007	**159.64**	**0.02**	**163**		
	2016	132.48	-	322		
pH	**1978**	**4.48**	**<0.01**	**23**	↑	↔
	1998	5.10	0.93	28		
	2007	5.02	0.27	150		
	2016	5.11	-	248		
Total Nitrogen (%)	**1998**	**1.14**	**<0.01**	**28**	↓	↓
	2007	**1.13**	**<0.01**	**26**		
	2016	0.87	-	248		
Bulk Density (g/cm^3)	2007	0.55	0.76	145	-	↔
	2016	0.54	-	247		

Table 3.1.3. *Trends in soil properties on* ***improved land****. Estimates of each property in each year are from linear mixed-effects models.* P*-values lower than 0.05 (bold text) indicate years where estimates are significantly different from 2016. The number of relevant soil samples in each year is also shown. "↔" represents non-significance in a trend, indicating stability and/or low sample size.*

Variable	Year	Estimate	*P*-value vs. 2016	n samples	Long-term trend	Short-term trend
Carbon concentration (g/kg)	1978	59.83	0.45	43	↔	↔
	1998	56.77	0.98	43		
	2007	53.00	0.20	216		
	2016	56.66	-	249		
pH	**1978**	**5.35**	**<0.01**	**50**	↑	↓
	1998	5.75	0.71	46		
	2007	**5.99**	**<0.01**	**230**		
	2016	5.78	-	323		
Total Nitrogen (%)	1998	0.52	0.14	45	↔	↔
	2007	0.53	0.08	43		
	2016	0.47	NA	321		
Olsen-Phosphorus (mg/kg)	**1998**	**41.31**	**<0.01**	**33**	↓	↔
	2007	23.56	0.98	43		
	2016	23.62	NA	321		
Bulk Density (g/cm^3)	**2007**	**0.95**	**<0.01**	**228**	-	↓
	2016	0.85	-	323		

Table 3.1.4. *Trends in soil properties in* ***woodland****. Estimates of each property in each year are from linear mixed-effects models.* P*-values lower than 0.05 (bold text) indicate years where estimates are significantly different from 2016. The number of relevant soil samples in each year is also shown. "↔" represents non-significance in a trend, indicating stability and/or low sample size.*

Variable	Year	Estimate	*P*-value vs. 2016	n samples	Long-term trend	Short-term trend
Carbon concentration (g/kg)	1978	134.93	0.09	15	↔	↔
	1998	151.98	0.52	17		
	2007	145.97	0.21	62		
	2016	166.91	-	88		
pH	**1978**	**4.07**	**<0.01**	**15**	↑	↔
	1998	4.64	0.84	17		
	2007	4.70	0.84	64		
	2016	4.68	-	88		
Total Nitrogen (%)	1998	0.97	0.18	16	↔	↔
	2007	0.72	0.25	16		
	2016	0.81	-	88		
Bulk Density (g/cm^3)	2007	0.58	0.06	59	-	↔
	2016	0.49	-	88		

Table 3.1.5. *Trends in soil properties on* ***acid grassland****. Estimates of each property in each year are from linear mixed-effects models.* P*-values lower than 0.05 (bold text) indicate years where estimates are significantly different from 2016. The number of relevant soil samples in each year is also shown. "↔" represents non-significance in a trend, indicating stability and/or low sample size.*

Variable	Year	Estimate	*P*-value vs. 2016	n samples	Long-term trend	Short-term trend
Carbon concentration (g/kg)	1978	219.27	0.36	8	↔	↔
	1998	233.46	0.28	7		
	2007	231.54	0.13	42		
	2016	192.82	-	75		
pH	**1978**	**4.18**	**0.02**	**8**	↑	↔
	1998	4.66	0.71	7		
	2007	4.54	0.10	42		
	2016	4.74	-	75		
Total Nitrogen (%)	1998	1.28	0.16	7	↔	↔
	2007	1.25	0.15	6		
	2016	1.13	-	75		
Bulk Density (g/cm^3)	2007	0.42	0.91	42	-	↔
	2016	0.42	-	75		

Table 3.1.6. *Trends in soil properties on* ***mountain, moor & heath****. Estimates of each property in each year are from linear mixed-effects models.* P*-values lower than 0.05 (bold text) indicate years where estimates are significantly different from 2016. The number of relevant soil samples in each year is also shown. "↔" represents non-significance in a trend, indicating stability and/or low sample size.*

Variable	Year	Estimate	*P*-value vs. 2016	n samples	Long-term trend	Short-term trend
Carbon concentration (g/kg)	1978	204.43	0.87	4	↔	↔
	1998	242.03	0.63	9		
	2007	251.36	0.35	38		
	2016	216.33	-	57		
pH	1978	3.97	0.11	4	↔	↔
	1998	4.80	0.65	9		
	2007	4.38	0.09	42		
	2016	4.68	-	62		
Total Nitrogen (%)	**1998**	**1.59**	**0.03**	**9**	↓	↔
	2007	1.48	0.09	6		
	2016	1.08	-	62		
Bulk Density (g/cm^3)	2007	0.36	*NA*	38	-	↔
	2016	0.38	-	62		

Table 3.1.7. *Trends in soil properties on* ***arable land****. Estimates of each property in each year are from linear mixed-effects models.* P*-values lower than 0.05 (bold text) indicate years where estimates are significantly different from 2016. The number of relevant soil samples in each year is also shown. "↔" represents non-significance in a trend, indicating stability and/or low sample size.*

Variable	Year	Estimate	*P*-value vs. 2016	n samples	Long-term trend	Short-term trend
Carbon concentration (g/kg)	1998	46.42	0.12	4	↔	↔
	2007	34.11	0.73	19		
	2016	35.49	-	22		
pH	1998	6.25	0.95	4	↔	↔
	2007	6.60	0.17	19		
	2016	6.22	-	22		
Bulk Density (g/cm^3)	2007	1.10	0.44	18	-	↔
	2016	1.05	NA	22		

Table 3.1.8. *Trends in soil properties in **improved grassland**. Estimates of each property in each year are from linear mixed-effects models.* P*-values lower than 0.05 (bold text) indicate years where estimates are significantly different from 2016. The number of relevant soil samples in each year is also shown. "↔" represents non-significance in a trend, indicating stability and/or low sample size.*

Variable	Year	Estimate	*P*-value vs. 2016	n samples	Long-term trend	Short-term trend
Carbon concentration (g/kg)	1978	61.51	0.52	42	↔	↔
	1998	58.53	0.96	39		
	2007	54.92	0.21	197		
	2016	58.73	-	227		
pH	**1978**	**5.34**	**<0.01**	**49**	↑	↓
	1998	5.69	0.51	42		
	2007	**5.93**	**<0.01**	**211**		
	2016	5.75	-	301		
Total Nitrogen (%)	1998	0.52	0.27	41	↔	↔
	2007	0.53	0.16	43		
	2016	0.49	-	299		
Olsen-Phosphorus (mg/kg)	**1998**	**35.55**	**<0.01**	**29**	↓	↔
	2007	25.43	0.41	43		
	2016	23.35	-	299		
Bulk Density (g/cm^3)	**2007**	**0.94**	**<0.01**	**210**	-	↓
	2016	0.84	-	301		

Table 3.1.9. *Trends in soil properties in **semi-improved grassland**. Estimates of each property in each year are from linear mixed-effects models.* P*-values lower than 0.05 (bold text) indicate years where estimates are significantly different from 2016. The number of relevant soil samples in each year is also shown. "↔" represents non-significance in a trend, indicating stability and/or low sample size.*

Variable	Year	Estimate	*P*-value vs. 2016	n samples	Long-term trend	Short-term trend
Carbon concentration (g/kg)	1978	53.48	0.09	11	↔	↔
	1998	53.64	0.13	13		
	2007	63.95	0.90	71		
	2016	64.53	-	165		
pH	**1978**	**5.14**	**0.02**	**9**	↑	↔
	1998	5.72	0.65	10		
	2007	5.72	0.39	57		
	2016	5.63	-	91		
Total Nitrogen (%)	1998	0.54	0.67	10	↔	↔
	2007	0.57	0.25	12		
	2016	0.52	-	91		
Olsen-Phosphorus (mg/kg)	1998	18.28	0.27	8	↔	↔
	2007	16.02	0.72	12		
	2016	15.25	-	91		
Bulk Density (g/cm^3)	2007	0.80	0.30	56	-	↔
	2016	0.75	-	90		

Table 3.1.10. *Trends in soil properties in* ***broadleaved woodland****. Estimates of each property in each year are from linear mixed-effects models.* P*-values lower than 0.05 (bold text) indicate years where estimates are significantly different from 2016. The number of relevant soil samples in each year is also shown. "↔" represents non-significance in a trend, indicating stability and/or low sample size.*

Variable	Year	Estimate	*P*-value vs. 2016	n samples	Long-term trend	Short-term trend
Carbon concentration (g/kg)	1978	65.24	0.24	7	↔	↔
	1998	68.64	0.34	5		
	2007	83.89	0.27	34		
	2016	110.98	-	40		
pH	1978	4.46	0.12	7	↔	↔
	1998	5.18	0.76	5		
	2007	5.30	0.34	34		
	2016	5.06	-	40		
Bulk Density (g/cm^3)	2007	0.72	0.06	32	-	↔
	2016	0.57	-	40		

Table 3.1.11. *Trends in soil properties in* ***coniferous woodland****. Estimates of each property in each year are from linear mixed-effects models.* P*-values lower than 0.05 (bold text) indicate years where estimates are significantly different from 2016. The number of relevant soil samples in each year is also shown. "↔" represents non-significance in a trend, indicating stability and/or low sample size.*

Variable	Year	Estimate	*P*-value vs. 2016	n samples	Long-term trend	Short-term trend
Carbon concentration (g/kg)	1978	192.80	0.36	8	↔	↔
	1998	231.74	0.49	12		
	2007	201.80	0.58	28		
	2016	212.41	-	48		
pH	**1978**	**3.76**	**<0.01**	**8**	↑	↔
	1998	4.24	0.84	12		
	2007	4.16	0.22	30		
	2016	4.27	-	48		
Total Nitrogen (%)	**1998**	**1.24**	**0.02**	**12**	↓	↔
	2007	0.82	0.43	10		
	2016	0.88	-	48		
Bulk Density (g/cm^3)	2007	0.42	0.75	27	-	↔
	2016	0.41	-	48		

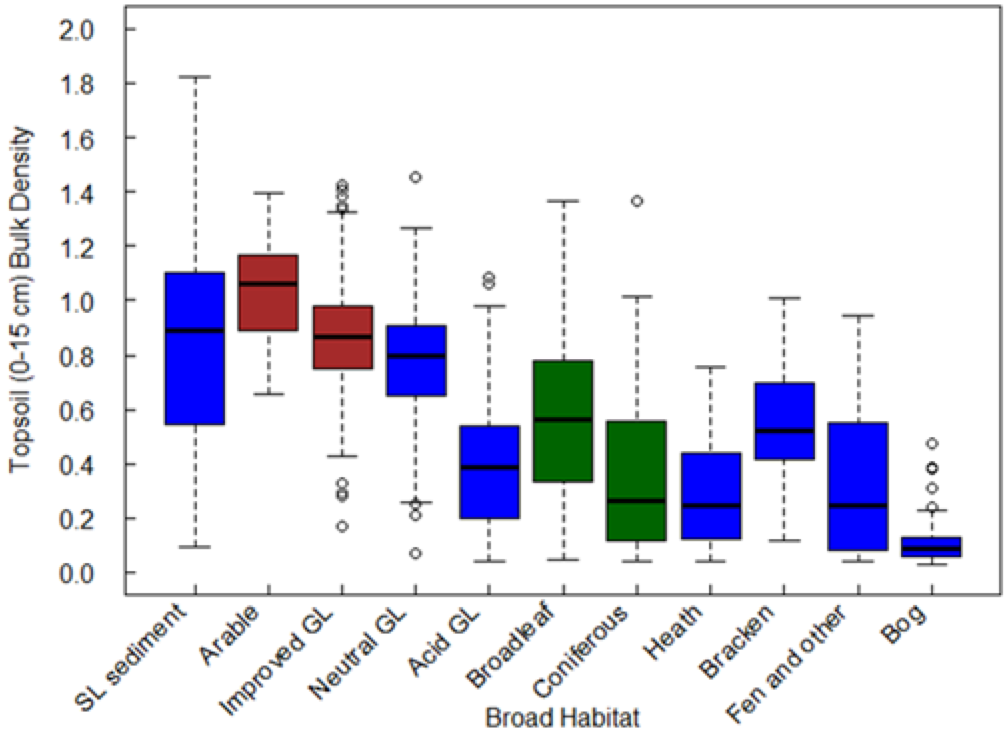


Figure 3.1.6. *The distribution of bulk density (g/cm^3) across broad habitat types in GMEP 2013-2016. Thick lines represent medians, boxes represent the interquartile range (IQR), and whiskers represent 1.5*IQR. SL = supra-littoral, GL = grassland.*

3.1.3 Discussion

Improvements

New analyses within more specific reporting categories show an increase in the pH of acid grassland and semi-improved grassland since 1978 (Figures 3.1.3 & 3.1.4), suggesting a contribution to the overall trend reported for habitat land in the GMEP final report (Emmett and the GMEP team 2017). This reflects rapid reductions in acidic deposition over the last three decades. This recovery has now halted in improved land, perhaps reflecting current low levels of lime usage. However, on average soil pH remains above recommended levels for sustained production in improved land.

New analyses also show a decrease in total nitrogen in mountain, moor and heath soil since 1998 which is likely to be beneficial for native vegetation although the reasons for the decline have not been identified. They could be associated with recent reductions in N deposition and/or dilution of the soil nitrogen signal by carbon driven by nitrogen induced increases in plant productivity (Figure 3.1.3). Trends in soil properties on improved grassland mirror those for improved land as it was reported under GMEP (Figure 3.1.4). Broadleaved woodland showed no statistically significant trends, while coniferous woodland showed increases in pH and decreases in nitrogen and phosphorus, (Figure 3.1.5) all of which suggest recovery from previous acidification and eutrophication trends. Sample sizes for arable land in earlier sampling years are small, but preliminary analyses suggested declines in N and P since 1998 which will reduce risk of nutrient transfer to surface waters.

New analyses of bulk density demonstrate that in most categories, bulk density was stable since 2007. However, the reported significant decrease in bulk density on improved land, underpinned by a decrease on improved grassland, could indicate reduced compaction of improved soils in Wales (Table 3.1.8).

Within GMEP data, bulk density increases with land use intensity on improved land (Figure 3.1.6). Meanwhile coniferous woodlands tend to have lower bulk density than deciduous woodlands (Figure 3.1.6).

Areas for concern

Previous analyses have revealed declines in topsoil carbon on habitat land (Emmett and the GMEP team 2017), which is also supported in the present analysis (Figure 3.1.1. and Table 3.1.2). Analysis presented in the ERAMMP year 1 report 21 revealed that carbon declines are restricted to upland habitats, and may be related to changes in climate and upland vegetation – specifically heather cover (Alison et al. 2019). Finer-scale analyses presented here for acid grassland and mountain moor and heath are consistent with previous results, although declines are non-significant which could relate to decreased sample sizes (Figure 3.1.3, Tables 3.1.5 & 3.5.6).

Comments on analytical method

Results for the categories used in GMEP are largely as seen in the GMEP final report (Emmett and the GMEP team 2017). Minor differences in estimates have arisen because of (1) the removal of a small number of erroneous samples, and (2) slight changes in model structure (trends in different categories are now evaluated in separate models, rather than in a single model with a covariate for category type; this allows analysis of nested categories). One notable difference is that the overall increase in carbon concentration in woodland since 1978 is now considered marginally non-significant ($P = 0.09$). The statistical significance of this trend is apparently sensitive to slight changes in the data and methodology, although the overall magnitude of the trend remains as reported following GMEP (Emmett and the GMEP team 2017). As more data are collected under ERAMMP, this may emerge as a significant long-term positive trend.

Future work should develop the models used to estimate trends in soil properties from CS and GMEP data. Transformation of response variables to conform to a Gaussian error structure, or use of generalised linear mixed-effects models with non-normal error structures, could improve model fit and estimates of soil properties over time. As such, the estimates presented here are subject to change as (1) new data are received from ERAMMP monitoring and (2) as statistical modelling methods improve.

3.2 State: Pollinator abundance

The GMEP final report presented counts of pollinators at the scale of the 1km square (Emmett and the GMEP team 2017). Data on the diversity of butterflies, bees and hoverflies were further analysed during later work to understand high nature value farmland in Wales (Maskell et al. 2019b). This work highlighted positive relationships between butterfly diversity, broadleaved connectivity, hedgerows and improved land. Bee diversity was more sensitive to habitat diversity, while hoverfly diversity showed no significant relationships (Maskell et al. 2019b).

The magnitude of functions (e.g. pollination) carried out by insect groups recorded in GMEP are probably related to their abundance rather than their diversity (Kleijn et al. 2015). Furthermore, analysis is possible at a higher spatial resolution than the 1km square. Here we relate the abundance of eight pollinator groups to underlying habitats, using fine-scale data - specific to 200m transect sections. Where possible, habitats are linked to themes for reporting under SoNaRR.

3.2.1 Methods

Pollinator surveys

Two visits were made by trained insect surveyors – one in July and one in August - to each of 300 GMEP squares. Survey methods are derived from the Wider Countryside Butterfly Survey within the UK Butterfly Monitoring Scheme (Brereton et al. 2011). Visits were made between 10am and 4pm on warm, dry, calm days. During each visit, two 1km transects, divided into roughly 200m sections, were surveyed for butterflies (Lepidoptera: Rhopalocera), bees (Apoidea) and hoverflies (Syrphidae). Butterflies were identified to species-level; bees were identified as honeybees, bumblebees, megachilid solitary bees (family Megachilidae, collecting pollen on the abdomen) and other solitary bees; hoverflies were identified to one of three morphological groupings, broadly reflective of feeding strategies.

Pollinator transects were walked at an even pace. All identifiable insects observed within a 5m box around the observer were recorded. Temperature and wind speed (Beaufort scale) were recorded on-site for each transect. For more information on GMEP square selection and pollinator survey methodology, see the GMEP reports and appendices https://gmep.wales/.

Habitat surveys

Habitats surveys were carried out in all GMEP squares during the same year as the pollinator surveys. Every accessible land parcel in the square was assigned a UK Biodiversity Action Plant broad habitat type (JNCC 2019). We extracted the underlying broad habitat throughout every ~200m pollinator transect section by intersecting with habitat polygons in ArcGIS Desktop 10.6 (ESRI, Redlands, California). The broad habitat which accounted for the greatest proportion of each 200m transect section was allocated as the dominant underlying habitat. Transect sections were only included in these analyses if >100m intersected the allocated habitat type. Furthermore, we only included non-coastal habitats with >50 transect sections in analysis.

Data analysis

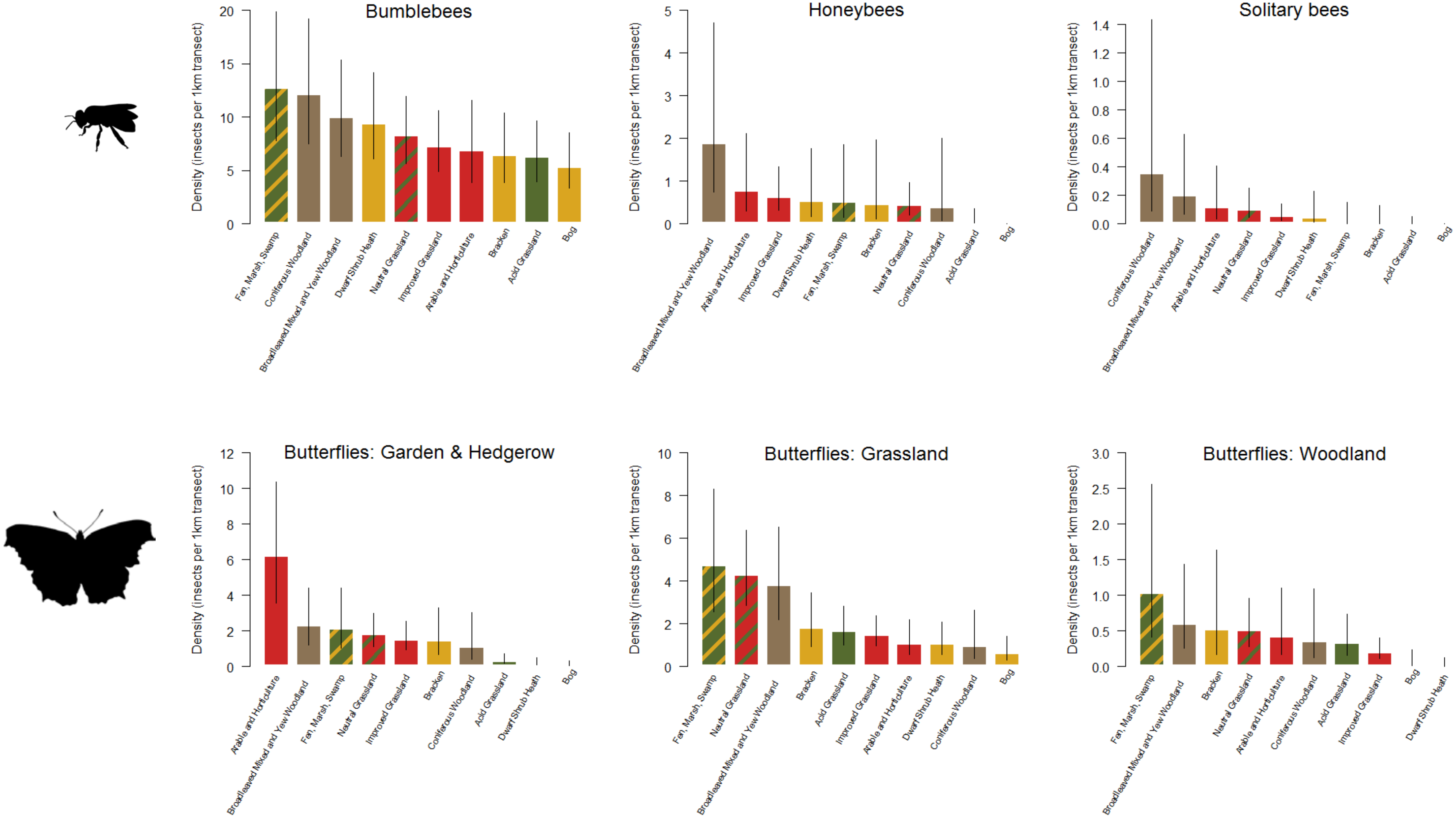
Data were analysed separately for three groups of bees (bumblebees, honeybees, and solitary bees; the latter including mining and leafcutter bees), three groups of butterfly (garden & hedgerow, grassland, and woodland) and two groups of hoverfly (aphid eaters and detritivores; herbivores had insufficient data). Broad habitat type was used to estimate the abundance of insects per 200m transect section. We used generalised linear mixed-effects models in the *R* package *glmmTMB* to account for spatial structure, repeated measurements, zero-inflation and overdispersion in the data (Brooks et al. 2017, R Core Team 2019).[3] We present predictions and 95% confidence intervals (CIs) for each insect group in each habitat type.[4]

[3] Specifically, we used "hurdle"-type models with a truncated negative-binomial error distribution for counts, conditional on a zero-inflation model with a binomial error distribution.
[4] Specifically, we present 95% CIs for predictions based on posterior predictive simulations (Brooks et al. 2017).

3.2.2 Results

Table 3.2.1 *Estimates of counts (per 1km transect) of eight groups of pollinating insects across 10 broad habitat categories. B'flies=butterflies; h'flies=hoverflies.*

Broad habitat	Bumblebees	Honeybees	Solitary bees	Garden/hedge b'flies	Grass-land b'flies	Wood-land b'flies	Aphid eating h'flies	Detritivorous h'flies
Broadleaved Woodland	10.09	1.90	0.20	2.38	3.87	0.61	4.65	5.95
Coniferous Woodland	12.21	0.41	0.36	1.14	1.01	0.37	5.84	5.18
Arable and Horticulture	6.96	0.80	0.12	6.26	1.13	0.44	11.28	5.14
Improved Grassland	7.36	0.65	0.06	1.58	1.53	0.21	2.95	2.61
Neutral Grassland	8.35	0.46	0.11	1.86	4.35	0.52	3.13	3.09
Acid Grassland	6.37	0.09	0.01	0.35	1.72	0.34	1.65	0.39
Fen, Marsh, Swamp	12.80	0.54	0.02	2.18	4.77	1.04	2.80	2.20
Dwarf Shrub Heath	9.50	0.56	0.05	0.21	1.11	0.03	1.73	0.33
Bog	5.44	0.00	0.00	0.11	0.67	0.05	0.66	0.09
Bracken	6.53	0.49	0.02	1.54	1.84	0.53	1.79	0.84


Bumblebees
Density (insects per 1km transect)
0
5
10
15
20
Fen, Marsh, Swamp
Coniferous Woodland
Broadleaved Mixed and Yew Woodland
Dwarf Shrub Heath
Neutral Grassland
Improved Grassland
Arable and Horticulture
Bracken
Acid Grassland
Bog
Honeybees
Density (insects per 1km transect)
0
1
2
3
4
5
Broadleaved Mixed and Yew Woodland
Arable and Horticulture
Improved Grassland
Dwarf Shrub Heath
Fen, Marsh, Swamp
Bracken
Neutral Grassland
Coniferous Woodland
Acid Grassland
Bog
Solitary bees
Density (insects per 1km transect)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Coniferous Woodland
Broadleaved Mixed and Yew Woodland
Arable and Horticulture
Neutral Grassland
Improved Grassland
Dwarf Shrub Heath
Fen, Marsh, Swamp
Bracken
Acid Grassland
Bog
Butterflies: Garden & Hedgerow
Density (insects per 1km transect)
0
2
4
6
8
10
12
Arable and Horticulture
Broadleaved Mixed and Yew Woodland
Fen, Marsh, Swamp
Neutral Grassland
Improved Grassland
Bracken
Coniferous Woodland
Acid Grassland
Dwarf Shrub Heath
Bog
Butterflies: Grassland
Density (insects per 1km transect)
0
2
4
6
8
10
Fen, Marsh, Swamp
Neutral Grassland
Broadleaved Mixed and Yew Woodland
Bracken
Acid Grassland
Improved Grassland
Arable and Horticulture
Dwarf Shrub Heath
Coniferous Woodland
Bog
Butterflies: Woodland
Density (insects per 1km transect)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Fen, Marsh, Swamp
Broadleaved Mixed and Yew Woodland
Bracken
Neutral Grassland
Arable and Horticulture
Coniferous Woodland
Acid Grassland
Improved Grassland
Bog
Dwarf Shrub Heath

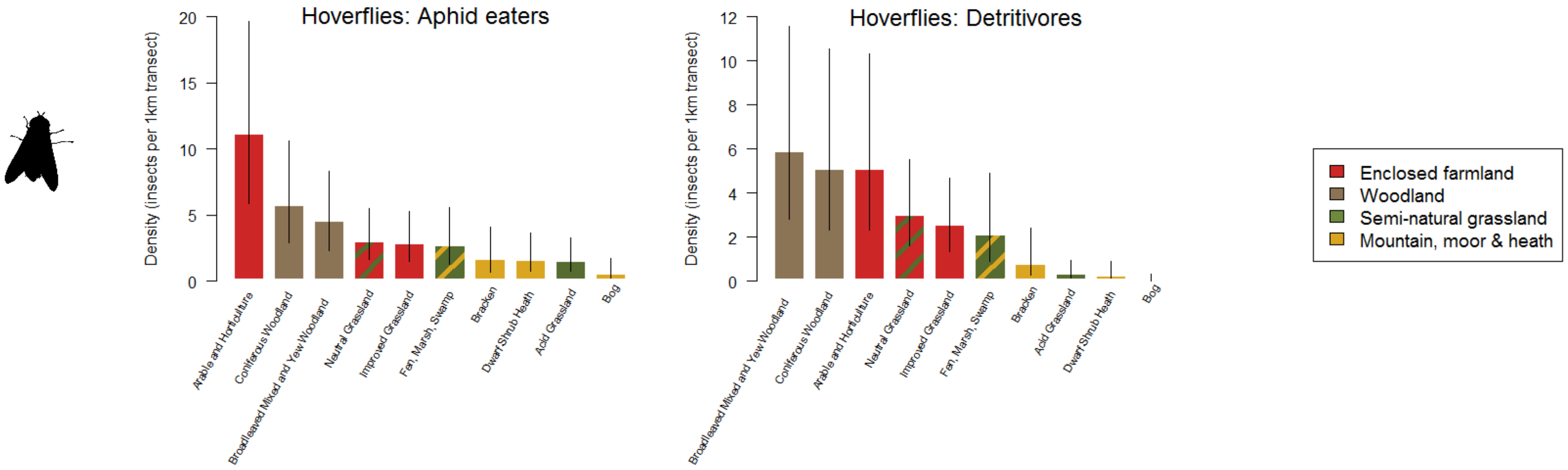


Figure 3.2.1. *Estimates of counts (per 1km transect; ±95% confidence intervals) of eight groups of pollinating insects within 10 broad habitat categories. Broad habitats with hatched lines fall mostly into one theme, but partly into another. Broad habitats are divided into themes by colour.* ***Enclosed farmland (red)****: Arable and horticulture; improved grassland; neutral grassland (although some neutral grassland is semi-natural grassland).* ***Woodland (brown)****: Broadleaved mixed and yew woodland, coniferous woodland.* ***Semi-natural grassland (green)****: Acid grassland; fen, marsh and swamp (mostly marshy grassland, but some mountain, moor & heath habitats).* ***Mountain, moor & heath (yellow)****: Dwarf shrub heath; bracken; bog. Estimates of insect density are derived from generalised linear mixed-effects models (see methods).*

Broad habitat had a significant effect on the abundance of all pollinator groups.[5] Further work would be required to determine which broad habitats are significantly different from others in terms of insect density, but we present averages in Table 3.2.1. Where the top of a bar for one broad habitat falls within the 95% confidence intervals of another broad habitat in Fig. 3.2.1, this could be interpreted as a non-significant difference.

[5] In all cases, GLMMs including broad habitat as a predictor had an AICc score (Akaike's Information Criterion with correction for small samples) at least 10 units lower than a model without an effect of broad habitat. Models including broad habitat had a substantially better fit to the data.

3.2.3 Discussion

Across all pollinator groups, four broad habitats supported consistently high abundances: Deciduous woodland, coniferous woodland, arable and horticultural and fen, marsh and swamp. Across SoNaRR themes, woodlands generally rank highest, followed by semi-natural grasslands and enclosed farmland. Within each insect group, the most abundant species underpin the effects seen in Figure 3.2.1. As butterflies were recorded to species level, we can confidently say what the dominant species were (Annex 3).

Woodlands clearly support high abundances of a wide variety of insect pollinators in Wales. Woodlands provide shelter, forage flowers and larval resources for many insect species counted in GMEP surveys. Deciduous woodland in particular is thought to rank highly among habitats in terms of nectar provision in Britain, with *Hedera helix* being a major contributor (Baude et al. 2016). Some types of solitary bee (leafcutter bees; family Megachilidae) nest in hollow twigs and stems which may be more abundant in woodlands.

Fen, marsh and swamp broad habitat mostly comprises marshy grassland, including the purple moor grass & rush pasture priority habitat. It is likely that marshy grasslands are providing larval food plants for butterflies; caterpillars of dominant species in butterfly groups for both grassland (the Meadow brown *Maniola jurtina* and the Small Heath *Coenonympha pamphilus*) and woodland (the Speckled Wood *Pararge aegeria* and the Ringlet *Aphantopus hyperantus*) feed on grass species which occur frequently in marshy grasslands (see Annex 3 for a breakdown of butterfly groups by species). Furthermore, common bumblebee species such as *Bombus terrestris* build nests in extensive grasslands.

Arable and horticultural land can provide floral resources in high abundance at certain times of year – e.g. where the crop is oilseed rape *Brassica napus* (Baude et al. 2016). That crop is also a food plant for some of the most common species in the butterfly group for garden and hedgerows – the cabbage whites (genus *Pieris*). These species are agricultural pests which also have potential as pollinators. Arable land is likely to support high abundances of aphid pests, which helps to explain high counts of aphidophagous hoverflies.

Wider countryside pollinator transect counts are clearly useful to show how abundances of pollinator groups, and thus pollination services, are distributed across Wales. These data have also been used to present bee counts on salt marshes in Wales into a national context (Davidson et al. 2020). Future work will use GMEP pollinator counts and mapped linear feature data to understand the effect of hedgerows on the abundance of insect groups. Such analyses will be bolstered by future pollinator transect surveys under ERAMMP, as well as integration with other, similar insect recording schemes to track change over time at a national scale. We will also review habitat groupings of butterflies outlined in Annex 3 to ensure confident interpretation of results

3.3 Trends: Veteran trees

Veteran tree results from the 2016 GMEP survey have not been presented previously. This report outlines the number of trees in each diameter at breast height (DbH) category in 2007 and 2016. These data were recorded as part of the mapping of individual trees, and are analysed as a representative sample of trees in Wales' wider countryside. Surveyors identified individual trees, and for up to 2 veteran trees of each species per 1km square, they recorded a number of condition attributes.

3.3.1 Methods

Individual trees

As part of the habitat mapping of each 1km square, surveyors were asked to record every individual tree outside of woodland. Where possible individual trees were recorded as a point feature. However, large numbers of uniformly scattered smaller trees were sometimes recorded as a "scattered trees" attribute of mapped areas. In this section we have only used the point feature data. The location, species and DbH were recorded for each tree. The numbers of individual trees by species have been extracted across 150 wider Wales 1km GMEP squares, which represent a stratified random sample of Wales' countryside. These data are presented below (Tables 3.3.1 and 3.3.2) as a percentage of the total number of trees of each species recorded.

Veteran trees

Surveyors recorded a maximum of two of each species per 1km square as veteran trees. In 2007 the guidance on how to identify a veteran tree was based on girth (Mitchell 1974; Annex 4). This information was also given to GMEP surveyors (2013-2016) but additionally guidance from the Farm Environment Plan was included (Annex 4). In addition to species and DbH, surveyors were asked to record a series of condition attributes on each veteran tree. These included whether there was a buffer zone around the tree, the type of tree i.e. lay, pollard or standard, the cover of ivy (<30% or >30%), cover of epiphytic species (rare, present or abundant), whether the tree was dead, the % of the canopy that was live (<25%, 25-49%, 50-89%, 90-100%), whether there was dead wood attached, dead or missing bark, lightning strikes, tears or scars, hollow trunks or major rot sites. The overall condition (Table 3.3.5 and Figure 3.3.2) was calculated from species that were recorded in high numbers in both surveys (Oak, Ash, Beech, Sycamore, Alder, Lime, Birch).

3.3.2 Results

- Most individual tree species are in the DbH category 21-50cm (Tables 3.3.1 and 3.3.2). Oak, Beech, Lime and Sweet chestnut trees tended to be larger (>75cm). In 2016 there were slightly fewer large oaks (>75cm) and more oaks in the 51-75cm category (Figure 3.3.1a). There were fewer large elm trees in the 2016 survey. The age distribution for ash trees remained similar in both years (Figure 1b).
- In the overall figures for condition (Table 3.3.5 and Figure 3.3.2) there were slightly more trees with a higher percentage of live canopy in 2016 and slightly less dead wood.
- Very few veteran trees have a buffer. This was the same in both surveys.
- The % cover of epiphytes (including Ivy) is lower in 2016 than 2007.

- In 2016 more trees were recorded as standards and less as lays or pollarded, suggesting a reduction in management.

Table 3.3.1: Percentage of individual trees (Number of squares with trees=95) in each DbH category by species in 2007.

Species	<3cm	3-20cm	21-50cm	50-75cm	75-1m	1-2m	>2m	Total no. of trees	Mean trees per square
Oak	0.1	4.1	18.3	19.3	36.2	16.7	3.0	951	10.0
Hawthorn	0.4	22.2	67.6	4.6	4.1	0.7	0	676	7.1
Ash	0.0	5.2	33.7	27.8	19.4	10.5	0.7	612	6.4
Sycamore	1.0	9.3	39.7	21.1	22.1	3.4	1.5	204	2.1
Willow	1.9	22.2	44.3	7.6	16.5	6.3	1.3	158	1.7
Rowan	1.3	36.1	43.9	7.7	7.7	2.6	0	155	1.6
Alder	1.0	6.7	46.2	13.5	14.4	12.5	2.9	104	1.1
Birch	0.0	15.4	53.8	10.6	17.3	2.9	0	104	1.1
Beech	1.1	2.2	16.7	5.6	46.7	24.4	3.3	90	0.9
Holly	0	21.3	60.7	11.5	4.9	1.6	0	61	0.6
Hazel	0	24.4	48.9	11.1	2.2	6.7	0	45	0.5
Field maple	0	6.7	43.3	26.7	13.3	10.0	0	30	0.3
Elder	3.6	64.3	25.0	7.1	0	0	0	28	0.3
Lime	0	0	3.7	3.7	55.6	33.3	3.7	27	0.3
Crab apple	0	14.3	52.4	14.3	19.0	0	0	21	0.2
Elm	6.3	18.8	25.0	12.5	12.5	12.5	12.5	16	0.2
Spruce - Sitka	25.0	43.8	18.8	12.5	0	0	0	16	0.2
Cherry	0	0	78.6	0	21.4	0	0	14	0.1
Prunus sp.	0	18.2	54.5	27.3	0	0	0	11	0.1
Sweet chestnut	0	0	18.2	9.1	0	45.5	27.3	11	0.1
Larch	0	11.1	55.6	11.1	11.1	11.1	0	9	0.1
Scots pine	0	44.4	33.3	11.1	0	0	0	9	0.1
Horse chestnut	12.5	50.0	0	12.5	12.5	12.5	0	8	0.1
Conifer sp.	0	28.6	57.1	14.3	0	0	0	7	0.1
Plum	0	28.6	71.4	0	0	0	0	7	0.1
Spruce - Norway	0	0	42.9	57.1	0	0	0	7	0.1
Apple	0	0	66.7	33.3	0	0	0	6	0.1
Poplar	0	0	60.0	0	20.0	20.0	0	5	0.1
Laburnum	0	25.0	75.0	0	0	0	0	4	0
Populus tremula	0	25.0	75.0	0	0	0	0	4	0
Walnut	0	0	0	33.3	66.7	0	0	3	0
Pine - Corsican	0	33.3	66.7	0	0	0	0	3	0
Yew	0	0	0	0	0	100	0	3	0
Hornbeam	0	0	0	0	0	100	0	2	0
Turkey oak	0	0	0	0	50.0	50.0	0	2	0
White beam	0	50.0	50.0	0	0	0	0	2	0
Cedrus sp.	0	0	0	0	100	0	0	1	0
Lawsons cypress	0	100	0	0	0	0	0	1	0
Dogwood	0	0	0	0	0	100	0	1	0
Fir - Douglas	0	0	0	0	0	100	0	1	0
Pine - Lodgepole	100	0	0	0	0	0	0	1	0
Populus sp	0	100	0	0	0	0	0	1	0
Quercus rubra	0	0	100	0	0	0	0	1	0
Guelder rose	0	100	0	0	0	0	0	1	0

Table 3.3.2. Percentage of individual trees (Number of squares with trees=128) in each DbH category by species in 2016.

Species	<3cm	3-20cm	21-50cm	50-75cm	75-1m	1-2m	>2m	Total no. of trees	Mean trees per square
Oak	0	3.9	20.9	32.4	22.1	17.3	3.0	837	5.6
Ash	1.5	12.2	27.2	33.1	15.5	8.4	1.9	523	3.5
Hawthorn	10.3	57.4	28.9	3.1	0.3	0	0	387	2.6
Sycamore	0.5	10.7	31.7	30.7	12.7	11.2	2.4	205	1.4
Willow	3.8	30.8	43.3	13.5	7.7	1.0	0	104	0.7
Rowan	9.2	35.5	42.1	10.5	1.3	0	0	76	0.5
Beech	0	12.1	22.4	15.5	12.1	31.0	6.9	58	0.4
Holly	0	45.5	38.6	15.9	0	0	0	44	0.3
Birch	0	11.6	44.2	41.9	2.3	0	0	43	0.3
Alder	0	18.4	36.8	26.3	5.3	10.5	2.6	38	0.3
Hazel	3.6	71.4	14.3	7.1	0	3.6	0	28	0.2
Apple	18.2	4.5	22.7	54.5	0	0	0	22	0.1
Horse chestnut	0	11.1	5.6	38.9	16.7	22.2	5.6	18	0.1
Elder	0	60.0	33.3	0	6.7	0	0	15	0.1
Larch	0	26.7	20.0	40.0	6.7	6.7	0	15	0.1
Cherry	7.1	21.4	42.9	14.3	0	7.1	7.1	14	0.1
Lime	0	0	15.4	0	15.4	53.8	15.4	13	0.1
Crab apple	0	7.7	53.8	7.7	7.7	23.1	0	13	0.1
Spruce - Sitka	20.0	10.0	60.0	0	10.0	0	0	10	0.1
Elm	0	22.2	55.6	11.1	11.1	0	0	9	0.1
Pine - Scots	0	0	62.5	37.5	0	0	0	8	0.1
Field Maple	0	28.6	57.1	14.3	0	0	0	7	0.0
Lawsons cypress	0	40.0	60.0	0	0	0	0	5	0.0
Pear	60	0	20.0	20.0	0	0	0	5	0.0
Norway spruce	0	14.3	14.3	57.1	14.3	0	0	7	0.0
Pinus sp.	0	0	50.0	25.0	0	25.0	0	4	0.0
Poplar	0	25.0	50.0	25.0	0	0	0	4	0.0
Quercus rubra	0	100	0	0	0	0	0	4	0.0
Plim	0	33.3	33.3	33.3	0	0	0	3	0.0
Bird cherry	0	33.3	33.3	0	0	33.3	0	3	0.0
Sweet chestnut	0	0	33.3	33.3	0	33.3	0	3	0.0
Yew	0	0	66.7	33.3	0	0	0	3	0.0
Hornbeam	0	0	100	0	0	0	0	2	0.0
Western red cedar	0	0	100	0	0	0	0	2	0.0
Walnut	0	0	100	0	0	0	0	1	0.0
Laburnum	0	0	100	0	0	0	0	1	0.0
Pine - Corsican	0	0	100	0	0	0	0	1	0.0

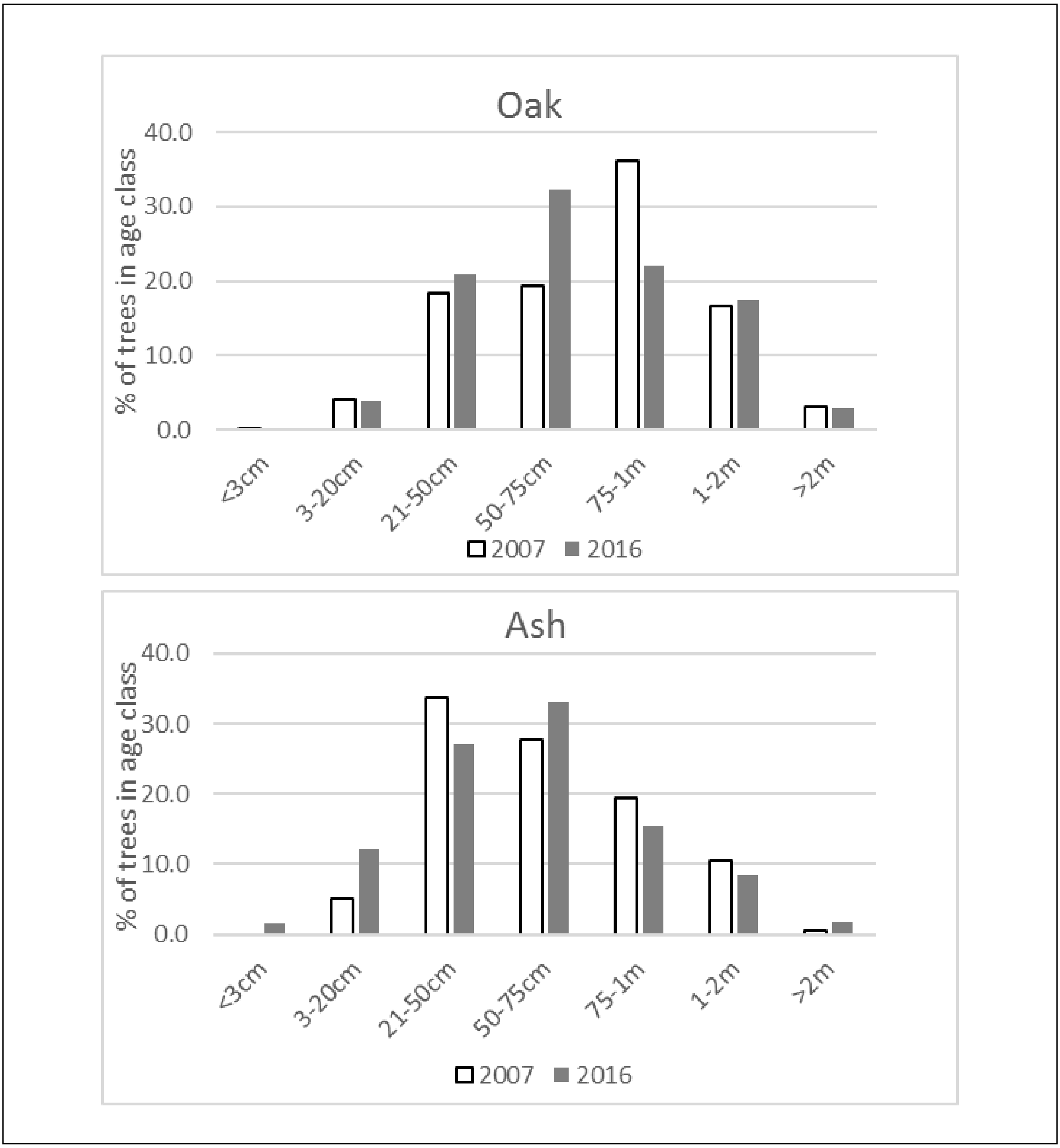


Figure 3.3.1. The distribution of trees in age classes in 2007 (white bars) and 2016 (grey bars) for (a) Oak and (b) Ash.

Table 3.3.3. % of trees recorded as veteran in each condition category by species in 2007 (<4 trees removed).

										Epiphytes			% of canopy live				Type of tree		
Species	**No of trees**	**Buffer**	**Tree dead**	**Missing limbs**	**Dead wood**	**Dead missing bark**	**Lightning strikes**	**Hollow trunk**	**Ivy cover >30%**	**rare**	**present**	**abund**	**<25**	**25-49**	**50-89**	**90-100**	**Lay**	**Pollard**	**Standard**
Oak	79	3.8	3.8	84.8	91.1	64.6	58.2	17.7	8.9	38.0	34.2	27.8	3.8	1.3	45.6	49.4	1.3	21.5	77.2
Ash	63	4.8	0.0	87.3	87.3	49.2	50.8	25.4	25.4	41.3	41.3	17.5	1.6	4.8	49.2	44.4	9.5	23.8	66.7
Hawthorn	35	0.0	0.0	62.9	85.7	71.4	48.6	22.9	2.9	34.3	25.7	40.0	0.0	0.0	54.3	45.7	22.9	20.0	57.1
Alder	23	0.0	0.0	73.9	82.6	60.9	43.5	8.7	8.7	52.2	34.8	13.0	0.0	4.3	47.8	47.8	4.3	39.1	56.5
Beech	21	0.0	0.0	66.7	81.0	57.1	47.6	9.5	0.0	61.9	28.6	9.5	0.0	0.0	14.3	85.7	4.8	38.1	57.1
Rowan	19	5.3	0.0	68.4	78.9	63.2	63.2	42.1	0.0	73.7	10.5	15.8	0.0	10.5	63.2	26.3	10.5	15.8	73.7
Birch	18	0.0	5.6	55.6	55.6	50.0	38.9	16.7	0.0	61.1	0.0	38.9	0.0	11.1	16.7	72.2	5.6	11.1	83.3
Willow	18	0.0	0.0	83.3	94.4	72.2	55.6	11.1	16.7	50.0	44.4	5.6	5.6	0.0	16.7	77.8	22.2	61.1	16.7
Field maple	9	0.0	0.0	55.6	77.8	44.4	66.7	22.2	0.0	22.2	33.3	44.4	0.0	0.0	22.2	77.8	22.2	11.1	66.7
Sycamore	9	0.0	0.0	44.4	55.6	22.2	22.2	0.0	11.1	66.7	11.1	22.2	0.0	0.0	44.4	55.6	11.1	33.3	55.6
Elm	6	0.0	0.0	66.7	83.3	83.3	83.3	0.0	16.7	33.3	66.7	0.0	33.3	0.0	0.0	66.7	0.0	83.3	16.7
Hazel	5	0.0	0.0	60.0	60.0	20.0	20.0	0.0	20.0	60.0	40.0	0.0	0.0	0.0	20.0	80.0	40.0	60.0	0.0
Holly	5	0.0	20.0	40.0	100.0	60.0	40.0	0.0	20.0	40.0	60.0	0.0	0.0	0.0	20.0	80.0	0.0	0.0	100.0
Lime	5	20.0	0.0	40.0	60.0	40.0	40.0	20.0	0.0	60.0	40.0	0.0	0.0	0.0	0.0	100.0	0.0	20.0	80.0
Sweet chestnut	5	20.0	0.0	80.0	80.0	60.0	80.0	40.0	0.0	0.0	80.0	20.0	0.0	0.0	40.0	60.0	0.0	40.0	60.0
Crab apple	4	0.0	0.0	75.0	100.0	75.0	75.0	0.0	25.0	0.0	50.0	50.0	0.0	0.0	75.0	25.0	0.0	0.0	100.0

Table 3.3.4. % of trees recorded as veteran in each condition category by species in 2016 (<4 trees removed)

										Epiphytes			% of canopy live				Type of tree		
Species	**No. of trees**	**Buffer**	**Tree dead**	**missing limbs**	**Dead wood**	**Dead missing bark**	**Lightning strikes**	**Hollow trunk**	**Ivy cover >30%**	**rare**	**present**	**abund**	**<25**	**25-49**	**50-89**	**90-100**	**Lay**	**Pollard**	**Standard**
Oak	96	2.1	2.1	86.5	87.5	70.8	59.4	21.9	9.4	71.9	25.0	3.1	1.0	4.2	22.9	71.9	0	4.2	95.8
Ash	37	2.7	0	81.1	67.6	43.2	48.6	27.0	16.2	73.0	21.6	5.4	0	5.4	18.9	75.7	2.7	18.9	78.4
Beech	16	6.3	0	81.3	50.0	43.8	50.0	12.5	0	50.0	43.8	6.3	6.3	0	0	93.8	25.0	18.8	56.3
Sycamore	15	6.7	0	73.3	53.3	26.7	66.7	26.7	6.7	73.3	26.7	0	6.7	0	20.0	73.3	13.3	13.3	73.3
Alder	6	0	0	83.3	83.3	50.0	33.3	66.7	0.0	83.3	16.7	0	0	0	0	100	0	50.0	50.0
Lime	6	0	0	16.7	50.0	0.0	50.0	16.7	0.0	83.3	16.7	0	0	0	0	100	0	16.7	83.3
Birch	4	0	0	75.0	50.0	50.0	75.0	50.0	0.0	25.0	25.0	50.0	0	0	25.0	75.0	0	0	100
Crab apple	4	0	0	100	75.0	75.0	25.0	50.0	25.0	75.0	0	25.0	0	0	0	100	0	0	100
Willow	4	0	0	0	75.0	0.0	75.0	25.0	0	100	0	0	0	0	0	100	0	25.0	75.0

Table 3.3.5: % of trees in each condition category in 2007 and 2016. Only those species recorded in both surveys (>4 trees) were included (Oak, Ash, Beech, Sycamore, Alder, Lime, Birch)

Category	2007	2016
Buffer	2.9	2.7
Tree dead	1.7	1.1
Missing limbs	77.9	79.8
Dead wood	84.2	75
Dead missing bark	57.1	54.8
Lightning strike	50.8	55.9
Hollow trunk	16.7	25
Ivy cover >30%	12.5	9
Epiphytes - Rare	45.8	70.7
Epiphytes - Present	33.3	24.5
Epiphytes - Abundant	20.8	4.8
Canopy live 90-100%	55.8	77.7
Canopy live 50-89%	39.2	17.6
Canopy live 25-49%	2.9	3.2
Canopy live <25%	2.1	1.6
Standard	66.25	85.1
Lay	6.3	3.7
Pollard	27.5	11.2

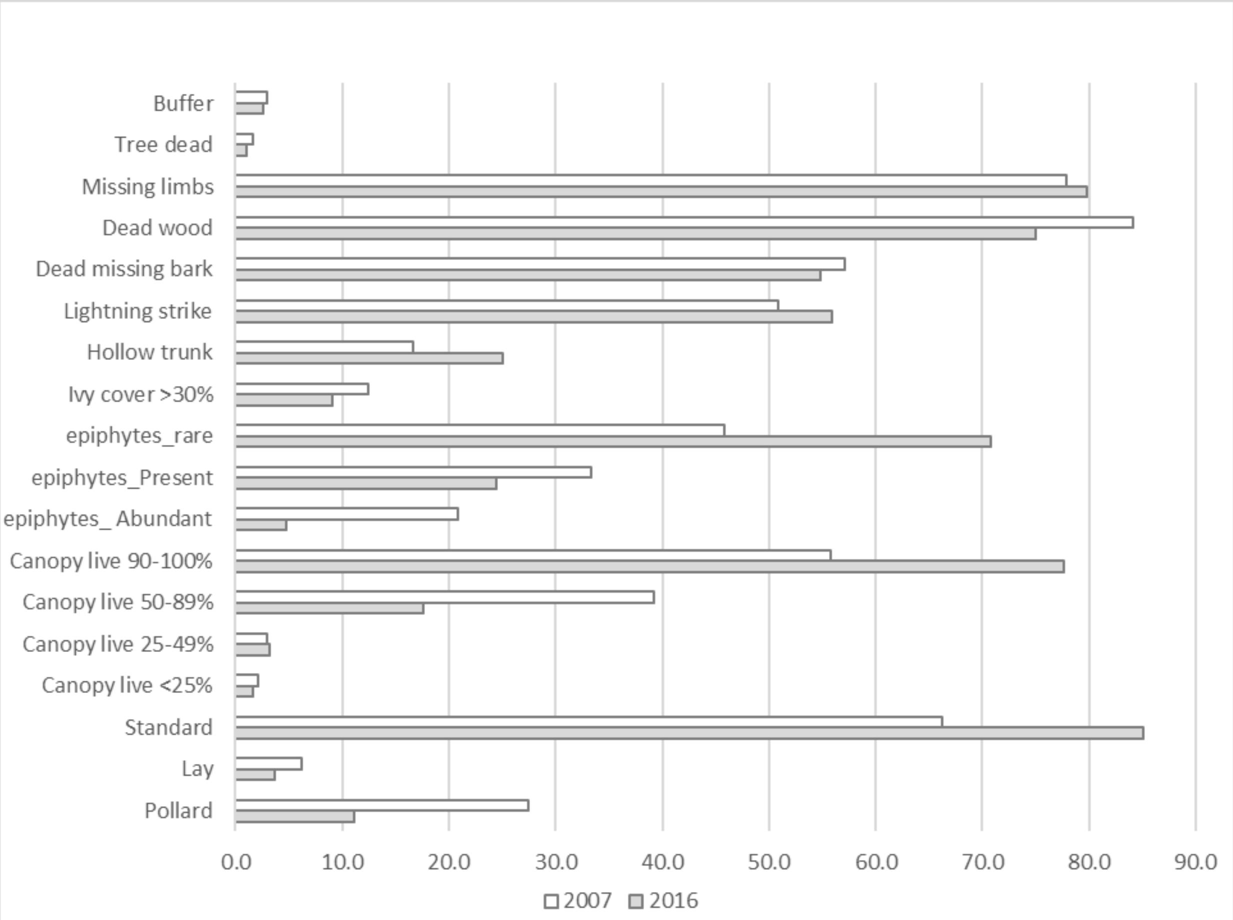


Figure 3.3.2. The percentage of trees identified as veteran in each condition category 2007 and 2016. Only those species recorded in both surveys (>4 trees) were included (Oak, Ash, Beech, Sycamore, Alder, Lime, Birch)

3.3.3 Discussion

These are preliminary results from the data collected on veteran trees in 2007 and 2016. The recording of individual trees by species and DbH provides a significant amount of data on the age distribution of tree species across the Welsh countryside. Most tree species tend to be recorded as DbH 21-50cm with a more limited number of species found as larger trees.

There were more veteran tree species recorded in 2007 than 2016. It is possible that this is because definitions of a veteran tree were tightened in the 2016 survey, with guidance given in training about what was likely to be defined as veteran. In addition, the time constraints and the restriction to 2 trees per species per square were emphasised in GMEP. The veteran tree data cannot be used to indicate distribution of trees, but can provide useful information about the condition of those trees. There are some identifiable trends; the amount of live canopy has increased (and conversely the amount of dead material has decreased). Epiphyte cover has decreased (including the cover of Ivy). Few veteran trees have buffers, while management of veteran trees may have decreased with fewer trees pollarded or lays. In terms of habitat, the loss of dead material and decreased epiphyte cover may be undesirable. The lack of a buffer is also likely to be undesirable. Further analyses of these data can be undertaken to clarify trends and focus on key messages.

4 Analyses for Enclosed Farmland

4.1 Trends: Vegetation condition and species richness

The Glastir Monitoring and Evaluation Programme (GMEP) final report presented an analysis of trends in condition of woodland, improved land and "habitat" land (all non-woodland, non-improved land; Emmett and the GMEP team 2017). The report presented short- and long-term increases in the total species richness of vascular plants on improved grassland, but only short-term increases in the richness of positive indicator species (https://jncc.gov.uk/our-work/common-standards-monitoring-guidance/). It also presented apparently stable (non-significant) trends in condition of arable land in terms of (1) total species richness of vascular plants and (2) the richness of annual forbs. Further analysis in the ERAMMP year 20 report (Maskell et al. 2019a) consolidated these findings, after including neutral grassland with >25% *Lolium* or *Trifolium repens* in the improved grassland category.

Further work was required to assess trends in condition of improved and semi-improved grassland based on a tailored list of positive indicator species, rather than a generic list relevant to all semi-natural habitats. Furthermore, some negative indicator species needed to be removed from the analysis of overall vascular plant species richness to ensure that trends are not underpinned by undesirable species.

Here we improve reporting of enclosed farmland condition in three ways:

1) We report on semi-improved grassland as well as improved grassland and arable land. Further analysis of the condition of semi-natural grassland, elsewhere in this report, identifies that the vast majority of neutral grassland is not semi-natural (i.e. NVC MG4, MG5 or MG8). As such, neutral grassland is presented in the "semi-improved grassland" category.
2) For each reporting category, we derive condition as the species richness of positive indicators specifically relevant to that category. Species lists were reviewed and amended by SoNaRR technical leads at NRW to ensure that they were fit for purpose.
3) For each reporting category, in the analysis of overall species richness we remove a specific list of species which are negative indicators for that category. Species lists were reviewed and amended by SoNaRR technical leads at NRW to ensure that they were fit for purpose.

4.1.1 Methods

Vegetation surveys

In each 1km square, plant species presence and cover was recorded in different sizes and types of vegetation plot (Emmett and the GMEP team 2017, Wood et al. 2017). Random points marking the position of five random or 'nested' plots (X plots) in each square were determined prior to the field survey. The locations, type and numbers of other kinds of plot were determined based on a rule-set, using the 'nested' plots as a starting point (or based on other mapping exercises). For more information on GMEP square selection and vegetation sampling methodology, see the GMEP reports and appendices https://gmep.wales/. Three particular plot types are relevant to this report:

1) Nested plots to provide a random sample of common vegetation types (X plots). Only the inner 2x2m area of these plots is used here for consistency across plot types and survey years.
2) Targeted 2x2m plots to sample Priority Habitats and locations eligible for Glastir (Y plots).
3) Unenclosed 2x2m plots to sample unenclosed Broad Habitats (U plots).

Data analysis

For each of three reporting categories (semi-improved grassland, improved grassland and arable), we extracted the relevant vegetation plots from Countryside Survey (CS) and GMEP surveys. Plots recorded as neutral grassland broad habitat are included in the semi-improved grassland category, except those with >25% cover of *Lolium* or *Trifolium repens* which are included in the improved grassland category. We included random plots ("X plots") as well as stratified random plots from unenclosed habitats ("U plots") and plots targeted to priority habitats ("Y plots") in the analysis (Wood et al. 2017). We calculated the richness of positive indicator species, and overall vascular plant species richness excluding negative indicators, using to category-specific species lists reviewed by NRW technical leads. For arable land, we treat all annual forb species as positive indicators. Positive and negative species lists for improved and semi-improved grassland are presented in Annex 5.

We analysed trends in species richness using linear mixed-effects models (LMMs) in the R package nlme (Pinheiro et al. 2019, R Core Team 2019). Species richness was log-transformed to ensure model residuals resembled a Gaussian distribution. We used a fixed effect for survey year with a correlation structure to account for repeated measures in CS and GMEP surveys.

4.1.2 Results

Semi-improved grassland: Condition

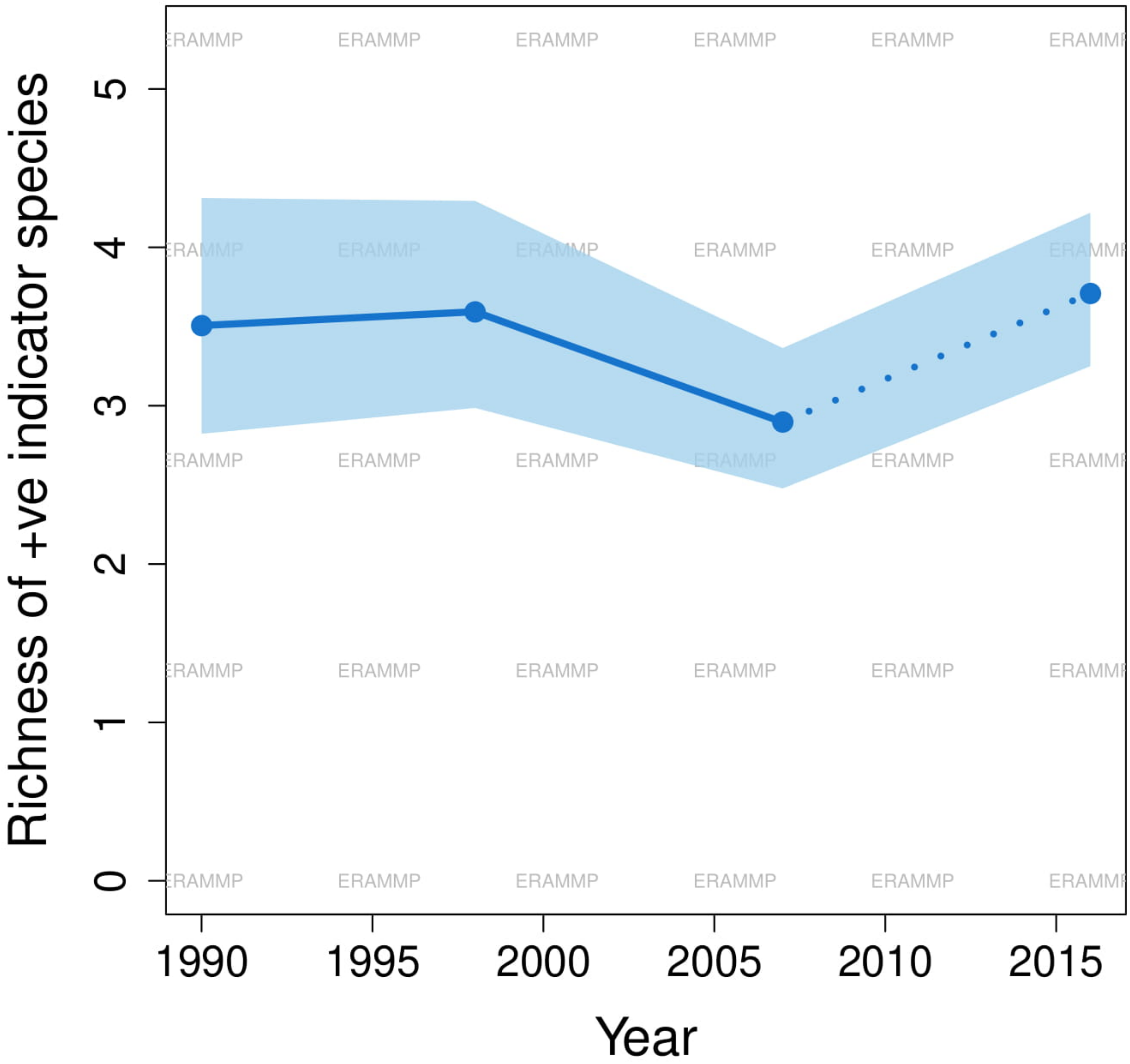


Figure 4.1.1. Richness of positive indicator species in vegetation plots on semi-improved grassland from 1990-2016. Blue dots represent estimates from a linear mixed-effect model, including year as a fixed effect. The light blue area above and below each estimate represents 95% confidence intervals. Data from 1990-2007 are from Countryside Survey; data from 2016 are from the Glastir Monitoring and Evaluation Programme.

Table 4.1.1. *Estimates of richness of positive indicator species in vegetation on semi-improved grassland from 1990-2016. Estimates of richness of positive indicator species in vegetation on semi-improved grassland from 1990-2016. P-values are shown for pairwise comparisons between GMEP 2016 and other survey years. The number of plots included in the analysis for semi-improved grassland is also shown. "↔" represents non-significance in a trend, indicating stability and/or low sample size.*

Year	Species richness estimate	*P*-value vs. 2016	Number of plots	Long-term trend	Short-term trend
1990	3.51	0.65	50	↔	↑
1998	3.59	0.78	68		
2007	2.90	**0.01**	121		
2016	3.71	NA	166		

Semi-improved grassland: Species richness

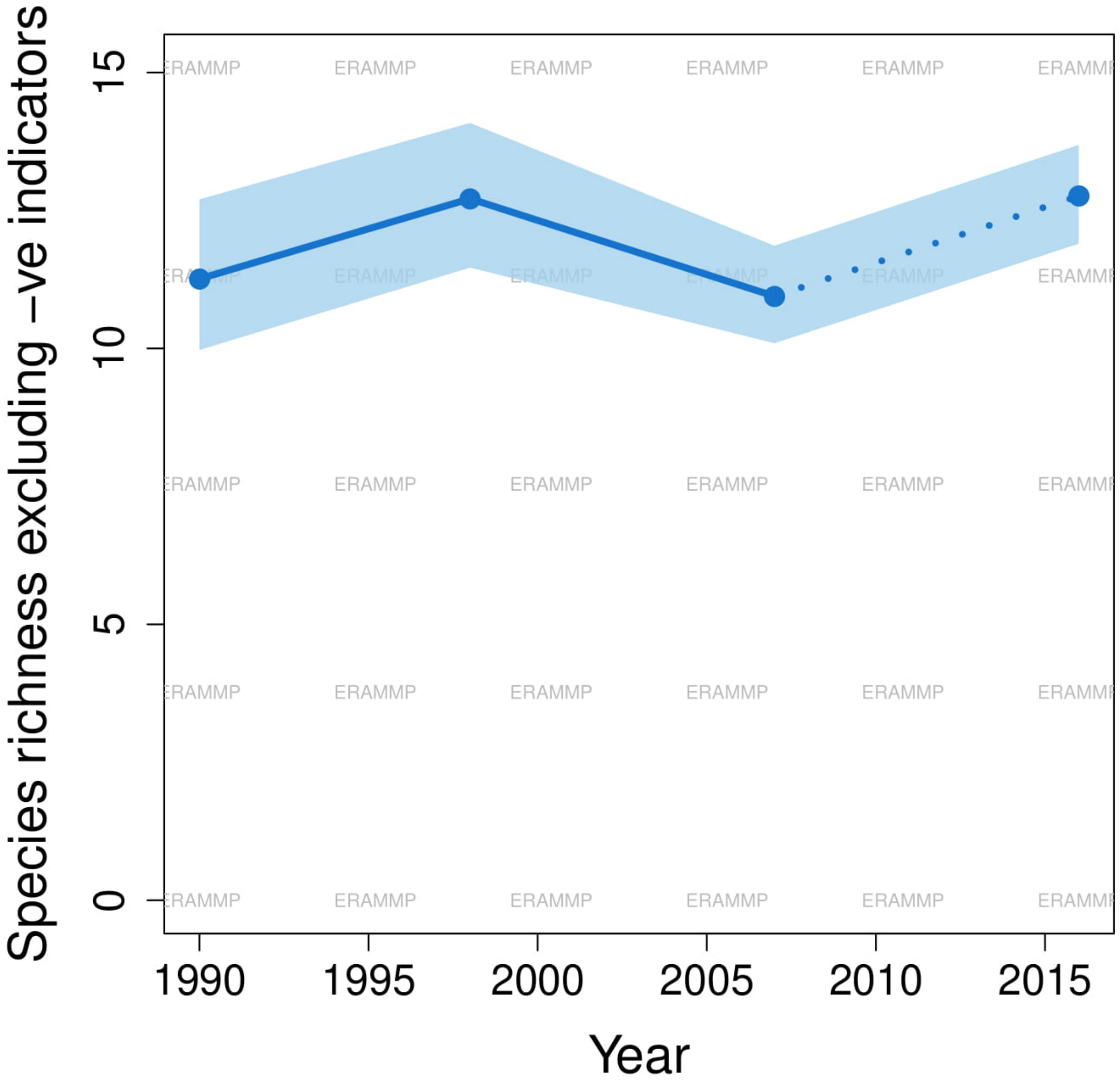


Figure 4.1.2. Species richness in vegetation plots on semi-improved grassland from 1990-2016 (excluding negative indicator species). Blue dots represent estimates from a linear mixed-effect model, including year as a fixed effect. The light blue area above and below each estimate represents 95% confidence intervals. Data from 1990-2007 are from Countryside Survey; data from 2016 are from the Glastir Monitoring and Evaluation Programme.

Table 4.1.2. *Estimates of Species richness in vegetation plots on semi-improved grassland from 1990-2016 (excluding non-native species).Estimates of Species richness in vegetation plots on semi-improved grassland from 1990-2016 (excluding non-native species).* P-*values are shown for pairwise comparisons between GMEP 2016 and other survey years. The number of plots included in the analysis for semi-improved grassland is also shown. "↔" represents non-significance in a trend, indicating stability and/or low sample size.*

Year	Species richness estimate	*P*-value vs. 2016	Number of plots	Long-term trend	Short-term trend
1990	11.26	0.08	50	↔	↑
1998	12.71	0.95	68		
2007	10.95	**0.01**	121		
2016	12.76	NA	166		

Improved grassland: Condition

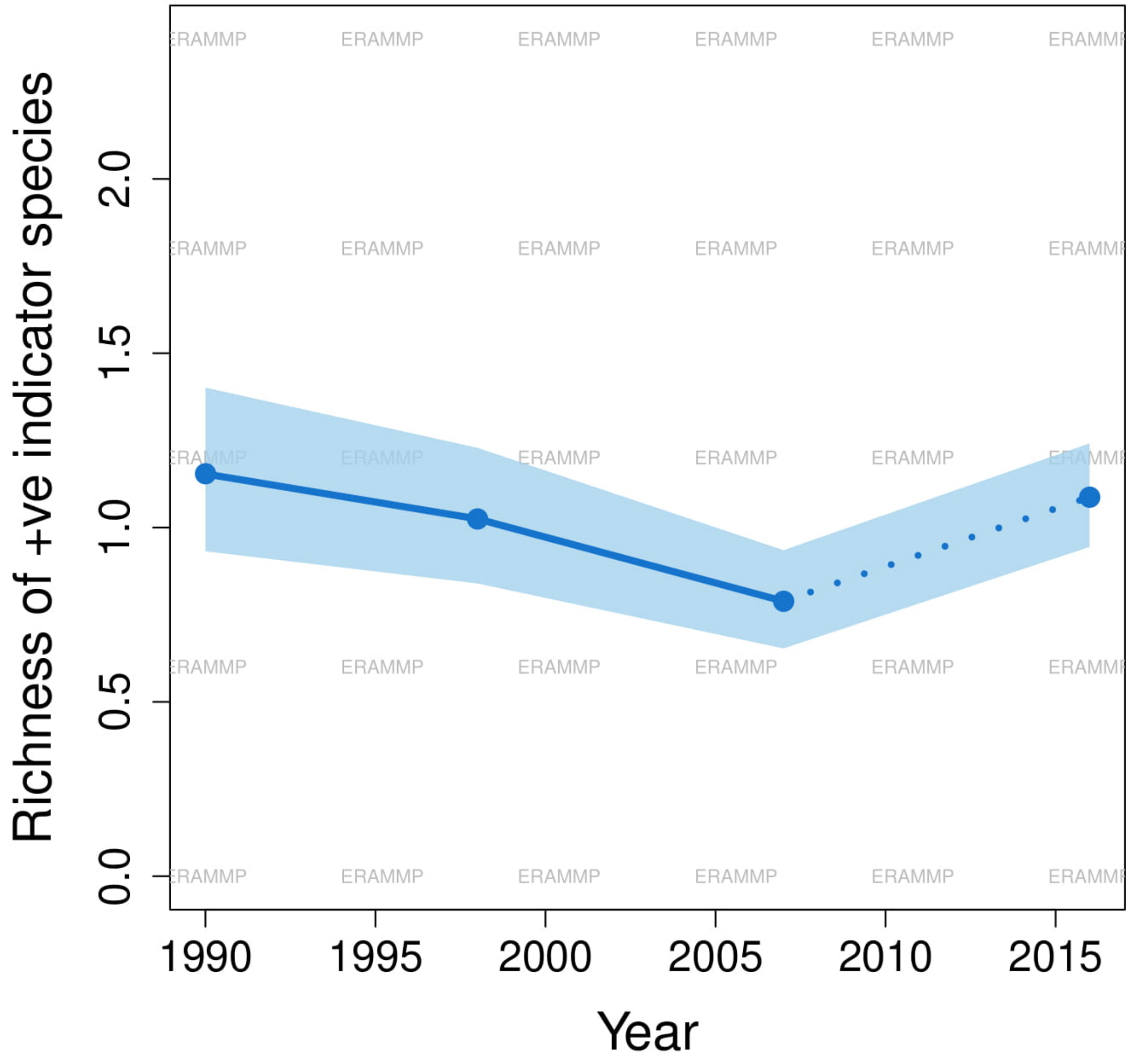


Figure 4.1.3. Richness of positive indicator species in vegetation plots on improved grassland from 1990-2016. Blue dots represent estimates from a linear mixed-effect model, including year as a fixed effect. The light blue area above and below each estimate represents 95% confidence intervals. Data from 1990-2007 are from Countryside Survey; data from 2016 are from the Glastir Monitoring and Evaluation Programme.

Table 4.1.3. *Estimates of richness of positive indicator species in vegetation plots on improved grassland from 1990-2016. Estimates of richness of positive indicator species in vegetation plots on improved grassland from 1990-2016.* P-*values are shown for pairwise comparisons between GMEP 2016 and other survey years. The number of plots included in the analysis for improved grassland is also shown. "↔" represents non-significance in a trend, indicating stability and/or low sample size.*

Year	Species richness estimate	*P*-value vs. 2016	Number of plots	Long-term trend	Short-term trend
1990	1.15	0.62	104	↔	↑
1998	1.02	0.60	143		
2007	0.79	**<0.001**	251		
2016	1.09	NA	331		

Improved grassland: Species richness

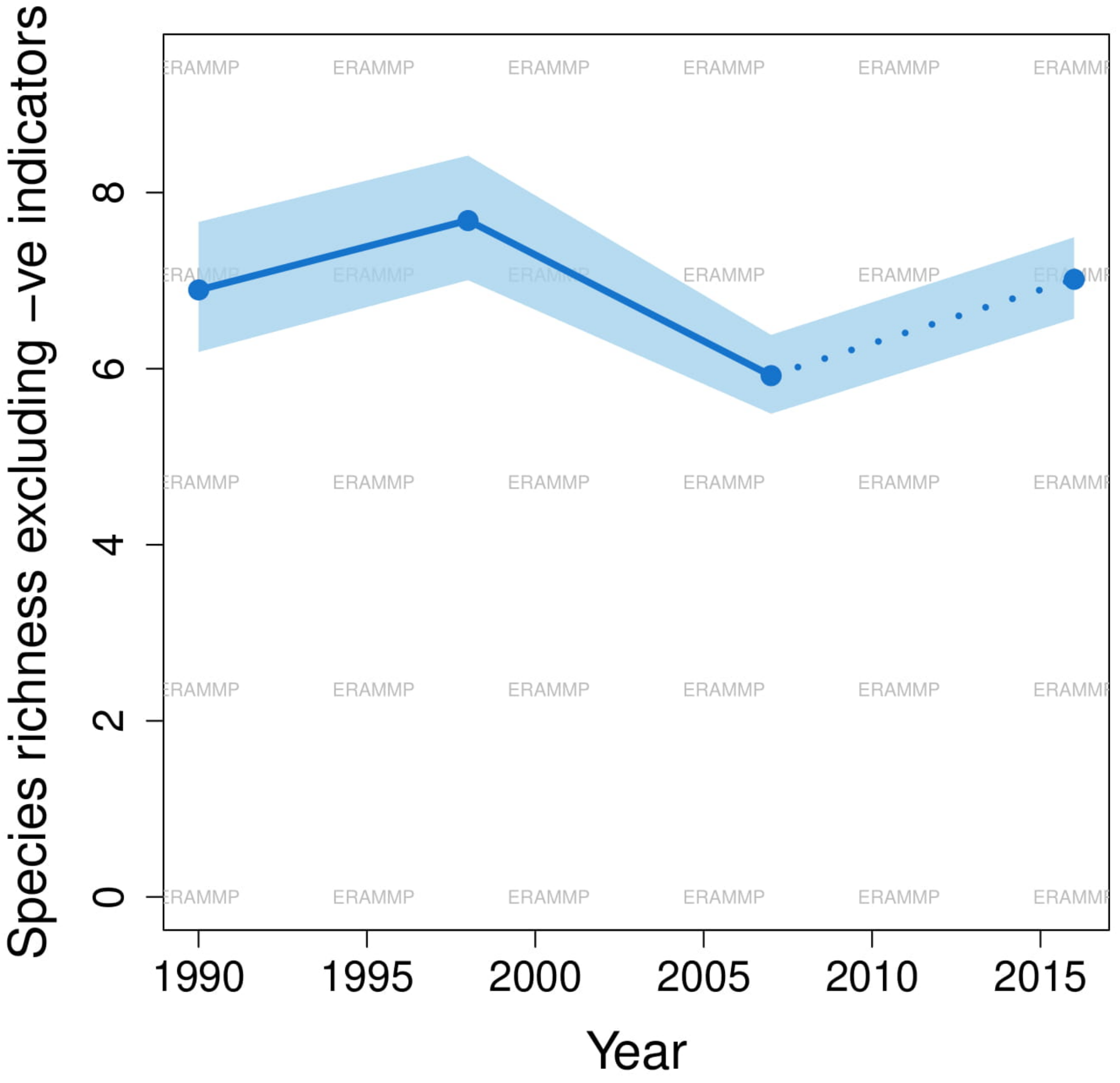


Figure 4.1.4. Species richness in vegetation plots on improved grassland from 1990-2016 (excluding negative indicator species). Blue dots represent estimates from a linear mixed-effect model, including year as a fixed effect. The light blue area above and below each estimate represents 95% confidence intervals. Data from 1990-2007 are from Countryside Survey; data from 2016 are from the Glastir Monitoring and Evaluation Programme.

Table 4.1.4. *Estimates of Species richness in vegetation plots on improved grassland from 1990-2016 (excluding non-native species).* P*-values are shown for pairwise comparisons between GMEP 2016 and other survey years. The number of plots included in the analysis for improved grassland is also shown. "↔" represents non-significance in a trend, indicating stability and/or low sample size.*

Year	Species richness estimate	*P*-value vs. 2016	Number of plots	Long-term trend	Short-term trend
1990	6.89	0.77	104	↔	↑
1998	7.68	0.11	143		
2007	5.92	**<0.001**	251		
2016	7.02	NA	331		

Arable: Condition

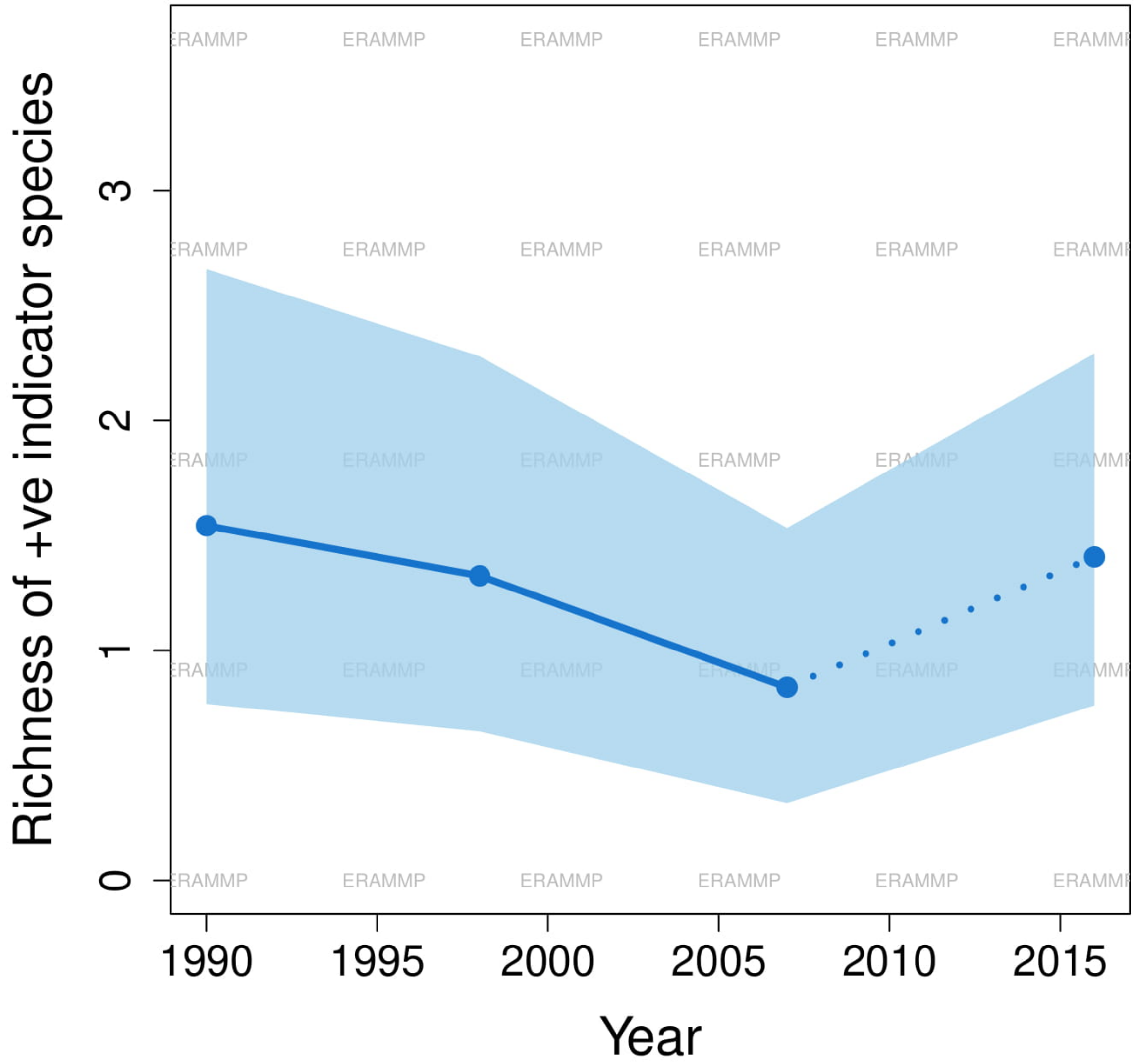


Figure 4.1.5. Richness of positive indicator species in vegetation plots on arable land from 1990-2016. Blue dots represent estimates from a linear mixed-effect model, including year as a fixed effect. The light blue area above and below each estimate represents 95% confidence intervals. Data from 1990-2007 are from Countryside Survey; data from 2016 are from the Glastir Monitoring and Evaluation Programme.

Table 4.1.5. *Estimates of richness of positive indicator species in vegetation plots on arable land from 1990-2016.* P*-values are shown for pairwise comparisons between GMEP 2016 and other survey years. The number of plots included in the analysis for arable land is also shown. "↔" represents non-significance in a trend, indicating stability and/or low sample size.*

Year	Species richness estimate	*P*-value vs. 2016	Number of plots	Long-term trend	Short-term trend
1990	1.54	0.83	17	↔	↔
1998	1.32	0.88	19		
2007	0.84	0.26	22		
2016	1.41	NA	23		

Arable: Species richness

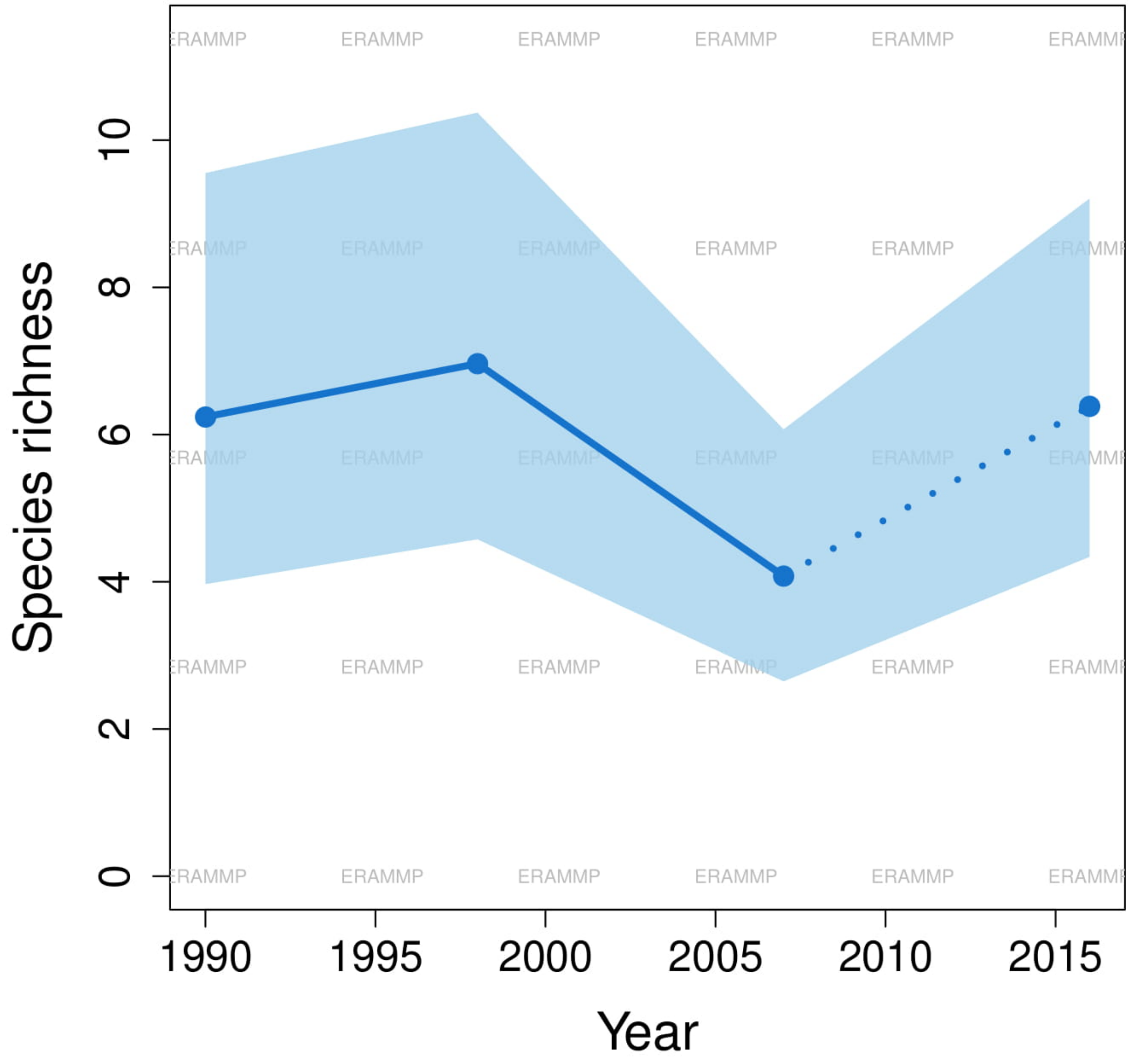


Figure 4.1.6. Species richness in vegetation plots on arable land from 1990-2016. Blue dots represent estimates from a linear mixed-effect model, including year as a fixed effect. The light blue area above and below each estimate represents 95% confidence intervals. Data from 1990-2007 are from Countryside Survey; data from 2016 are from the Glastir Monitoring and Evaluation Programme.

Table 4.1.6. *Estimates of Species richness in vegetation plots on arable land from 1990-2016 (excluding non-native species).* P-*values are shown for pairwise comparisons between GMEP 2016 and other survey years. The number of plots included in the analysis for arable land is also shown. "↔" represents non-significance in a trend, indicating stability and/or low sample size.*

Year	Species richness estimate	*P*-value vs. 2016	Number of plots	Long-term trend	Short-term trend
1990	6.24	0.94	17	↔	↔
1998	6.96	0.76	19		
2007	4.08	0.13	22		
2016	6.38	NA	23		

4.1.3 Discussion

These results depict trends in the condition of enclosed farmland in Wales at a higher definition than has been previously reported. New results for semi-improved grassland suggest increases in species richness, both of positive indicators and vascular plants, since 2007. However, these increases do appear to represent recovery following a drop in species richness up to 2007 (Figures 4.1.1 & 4.1.2). Furthermore, these results reveal that the number of vascular plant species recorded per 2x2m quadrat on semi-improved grassland is usually almost double that on improved grassland (Tables 4.1.2 & 4.1.4). The difference is greater for species richness of positive indicators; semi-improved grassland plots tended to contain three times as many species as improved grassland plots (Tables 4.1.1 & 4.1.3).

As in the ERAMMP Report 20 (Maskell et al. 2019a), there was a significant increase in the richness of positive indicator species and vascular plant species in improved grassland between 2007 and 2016 (Fig. 4.1.3 & 4.1.4, Table 4.1.3 & 4.1.4). However, the previously reported long-term increase in vascular plant species richness on improved grassland was not observed after removing negative indicators from species counts. Short term increases in improved grassland condition have occurred, but long-term increases in species richness were apparently underpinned by increases in undesirable species. Again, increases in species richness on improved grassland appear to represent recovery following a drop in species richness up to 2007 (Figures 4.1.3 & 4.1.4). As reported previously, there were no significant positive or negative trends in condition or species richness on arable land (Figures 4.1.5 & 4.1.6, Tables 4.1.5 & 4.1.6).

This work provides up-to-date condition trends for enclosed farmland based on species lists approved by NRW. Furthermore, this work demonstrates that removing negative indicators from species richness trends can improve understanding of enclosed farmland condition. Future field survey visits under ERAMMP will add another time-point to trends, providing further confirmation of the trajectory of enclosed farmland condition in Wales.

4.2 Trends: Hedgerow extent, structure, condition and species richness

This section collates results on hedgerow extent and condition from CS and GMEP.

Some of these results (changes in hedgerow management, changes in hedgerow height and trends in woody species richness) were calculated previously and included in the GMEP final report (Emmett and the GMEP team 2017), but they are brought together here with other results including the trend in ground flora species richness, the trend in condition of woody diversity plots, trends in hedgerow widths and the extent of woody linear features, all of which were not previously calculated.

4.2.1 Methods

Habitat mapping

As part of the habitat mapping of the 1km square, the length and structural condition of woody linear features was recorded. The term ‘woody linear features’ (WLFs) has been used to account for the tremendous diversity of WLFs to be found in the countryside including everything from a traditionally managed hedge to a planted avenue of trees or a line of old scrub which may at one time have been a managed hedge. WLFs fall into two broad categories based on the extent to which the trees within them take their natural shape.

- ‘Natural shape’ means unhindered/unmanaged growth for at least a decade. Where trees take their natural shape the feature will essentially be a line of trees or scrub.
- Where trees/scrub has been managed relatively recently the WLF will fall into the hedgerow category.

These analyses mostly use data from the second category; hedgerows.

Vegetation plots

In addition to the recording of structural features and measurement of overall length, fixed vegetation plots have been used to record the plant species composition of vegetation associated with hedge bottoms (1m x 10m B plots and H plots, Wood et al. 2017) and the number of woody species in each hedge and other useful information on structure and condition (Hedge Diversity Plots plots). The Hedge Diversity Plots span the width of the woody linear feature and are 30m long. In addition to species information, other data on the dimensions and condition of the feature were collected as was information on the presence and width of adjacent buffer strips. These attributes contribute to an assessment of condition that allows progress to be measured against the UK Habitat Action Plan for hedgerows.

Hedgerow condition analysis

Countryside Survey has always worked closely with the UK BAP steering group for hedgerows (now called Hedgelink) to identify criteria for hedgerow condition assessment and to enable collection of suitable data to assess whether hedgerows are in ‘favourable condition’. Hedgerow condition assessment depends on recording hedgerow ‘attributes’, such as height and width, that have been given thresholds by the UKHAP Steering Group to indicate whether a particular hedgerow is in ‘favourable condition’.

The basic attributes deemed to be indicative of 'favourable condition' include:

1. Structural only
    - height >1m
    - width of the woody component >1.5m
    - Cross-sectional area (height x width) >3m
    - the degree of intactness of the hedgerow canopy
        - Vertical gappiness <10%
        - No gaps >5m wide
    - the height above ground at which the canopy starts <0.5m
    - <10% non-native species

2. Structural and margins (width of perennial herbaceous vegetation >1m)
    - undisturbed ground >2m adjacent to the hedgerow (all land)

3. Structural and margins (width of perennial herbaceous vegetation >1m)
    - undisturbed ground >2m adjacent to the hedgerow (on arable land only)

The plots fulfilling the criteria for the three categories, structural, structural and margins (<1m perennial veg. margin + >2m undisturbed ground) on all land - as well as those fulfilling criteria for structural and margins (<1m perennial veg. margin + >2m undisturbed ground) on arable land - have been counted and the proportion of the total number of Hedge Diversity plots in each category calculated. For GMEP this involved only using plots in squares from the Wider Wales sample.

The trends in height categories and hedgerow management types have been calculated using the mapping data. The proportion of the sample in the different categories has been derived and results are shown.

The trends in hedgerow width have also been calculated. Unlike height, width was not recorded in the field mapping so the trends have been calculated from the woody diversity plots where the surveyor recorded width in a number of categories. Woody diversity plots were first established in 1998 and only three width categories were used (<1m, 1-2m, >2m). In 2007 more detailed categories were introduced (<1m, 1-1.5m, 1.5-2m, 2-2.5m, 2.5-3m, 3-4m, 4-5m). Results are presented as the proportion of plots in each of the categories from 1998 to 2016 for the simpler categories and 2007-2016 for the more detailed categories.

In addition the diversity of woody species in D plots and the species richness of hedge and boundary plots have been calculated, for the latter, after having removed negative indicators (indicating eutrophication and disturbance) including *Urtica dioica, Rumex sp., Galium aparine, Poa annua, Cirsium arvense, Cirsium vulgare, Bromus hordeaceus, Seneco vulgaris* and *Stellaria media*. The trends over time have been derived.

The percentage of plots where cover of docks (*Rumex* sp.), cleavers (*Galium aparine)* and nettles (*Urtica dioica*) is greater than 20% has been calculated (Table 4.2.7).

Extent of woody linear features analysis

National estimates for woody linear feature types (WUS- hedgerows and WNS- lines of trees) (in '000s km) were achieved by calculating a mean length for each feature type for the sample squares within a Land Class; then multiplying this figure by the number of 1km squares in the Land Class. This calculation gives an estimate of the total length in the Land Class and subsequently, by summation, of all Land Classes. Confidence intervals were obtained by repeatedly resampling squares within land classes (with replacement), and re-estimating mean length. Hence a bootstrap procedure of resampling squares within land classes. We use a consistent estimate statistical modelling approach for producing the national estimates, following Scot (2008). Adoption of this approach has implications for results. Because analyses involve data from all surveys then estimates for any one survey are influenced by information from all others. A consequence of this is that estimates cannot be made consistent across reporting occasions since the introduction of additional data with each new survey will produce updated estimates for previous surveys i.e. the acquisition of new information produces small revisions to previous findings. Missing information techniques (e.g. Dempster et al. 1977) use the correlation structure from the repeated measurements to judge where the most appropriate estimates lie. In practice the techniques work directly with the observed data and not by filling in missing values.

4.2.2 Results

Positive outcomes / improvements

I. A higher percentage of woody species diversity plots were in good condition in 2016 than 2007. This is particularly the case for structural variables, with only slight increases for hedges in structural condition with both >1m perennial veg. margins and >2m of undisturbed ground (structural + margins) both on all land and on arable land only (Table 4.2.1 and Figure 4.2.1).

II. Looking at condition metrics individually, hedgerows in 2016 were slightly wider, with fewer large gaps, the base height (where the canopy starts) was slightly greater than in 2007 and there was less perennial vegetation and undisturbed ground (Table 4.2.2 and Figure 4.2.2).

III. The trends in hedgerow width categories are presented in Tables 4.3.3 and 4.2.4 and figures 4.2.4 and 4.2.5. In the survey with more detailed categories between 2007 and 2016, hedgerow width has increased slightly with fewer hedgerows in the 1-1.5m category and more hedgerows recorded in the categories >2.5m. Since 1998 (when only three categories were recorded) hedgerow width has increased. In 1998 most hedgerows were estimated to be in the 1-2m category, in 2007 and 2016 there were fewer hedgerows in the 1-2m category and increases in the >2m with more hedgerows over 2m width in 2016.

IV. Diversity of species in the ground flora of hedgerow plots increased significantly ($p<0.001$) between 2007 and 2016 (Table 4.2.6 and figure 4.2.7) although it was not significantly higher than 1990 and 1998, richness had declined slightly (but not significantly) between 1998 and 2007.

V. There has been no significant change in the lengths of woody linear features (Table 4.2.8 and Figure 4.2.8). There is some indication that there is a trend towards decreasing hedgerow length and increasing length of lines of trees but this is not statistically significant.

Areas for concern

VI. The amount of new planting of hedgerows has decreased and there is evidence of a slight increase in frequency of cutting. There has been a decrease in laying and coppicing (Figure 4.2.3).

VII. Diversity of woody species in hedgerows has decreased significantly from 2007 ($p<0.001$) (Table 4.2.5 and Figure 4.2.6). Although 2016 diversity was slightly lower than 1998 it was not quite statistically significant ($p=0.054$)

Table 4.2.1. *The percentage of 30m long Hedge Diversity Plots in managed hedges in Wales that met condition criteria in 2007 (n=406) and 2016 (n=521)*

Year	2007	2016
STRUCTURAL ONLY	45	61.5
STRUCTURAL + MARGINS (ALL LAND)	15	16.9
STRUCTURAL + MARGINS (ARABLE LAND)	1.6	2.1

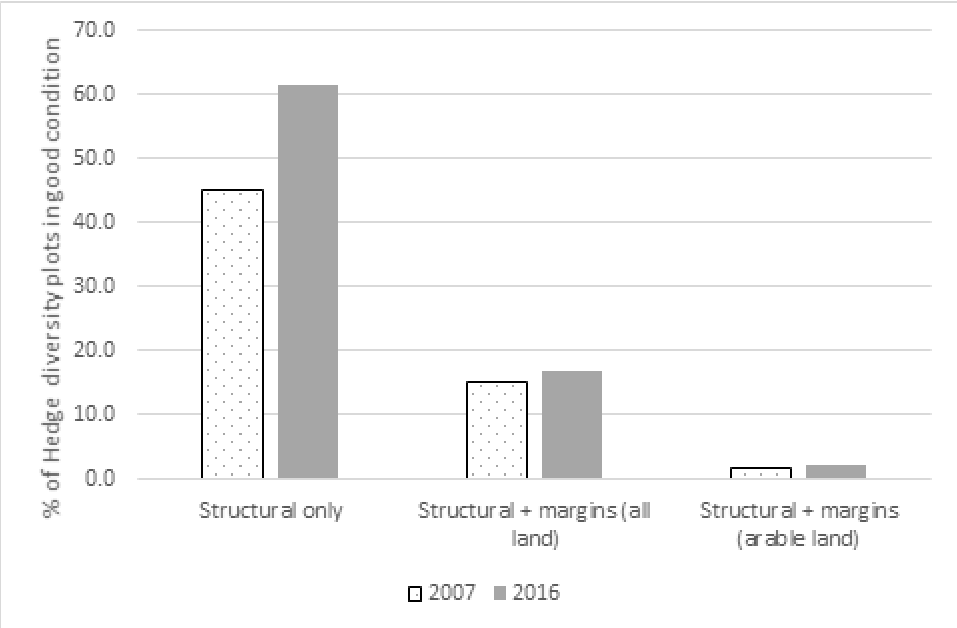


Figure 4.2.1. The percentage of 30m long Hedge Diversity Plots in managed hedges in Wales that met condition criteria in 2007 (n=406) and 2016 (n=521)

***Table 4.2.2.** Changes in the percentage of hedgerows meeting various condition criteria (using Hedge Diversity plots)*

Condition criterion	2007	2016
Height >1m	99.5	98.3
Width >1.5m	73.2	78.9
Height of base of canopy <0.5m	80	74.6
Non-native species at <10% cover	99.5	99.8
Cross-sectional area >3m2	71.3	72.7
<10% gaps	95.3	83.4
Vertical gappiness <5m	95.3	97.1
Undisturbed ground (2m) and perennial herbaceous cover (1m) from centre line of hedgerow (margins) (all land)	36.1	26.8
Margins (arable land)	3.2	2.6

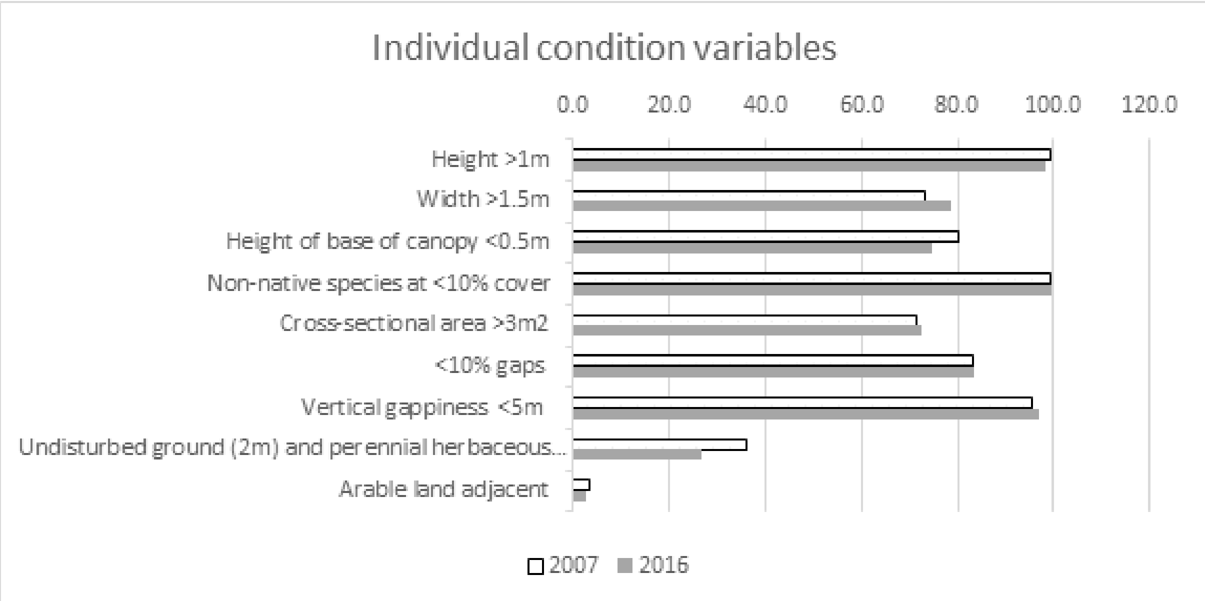


Figure 4.2.2. Changes in the proportion of plots reaching individual condition criteria in 2007 (CS) and 2016 (GMEP).

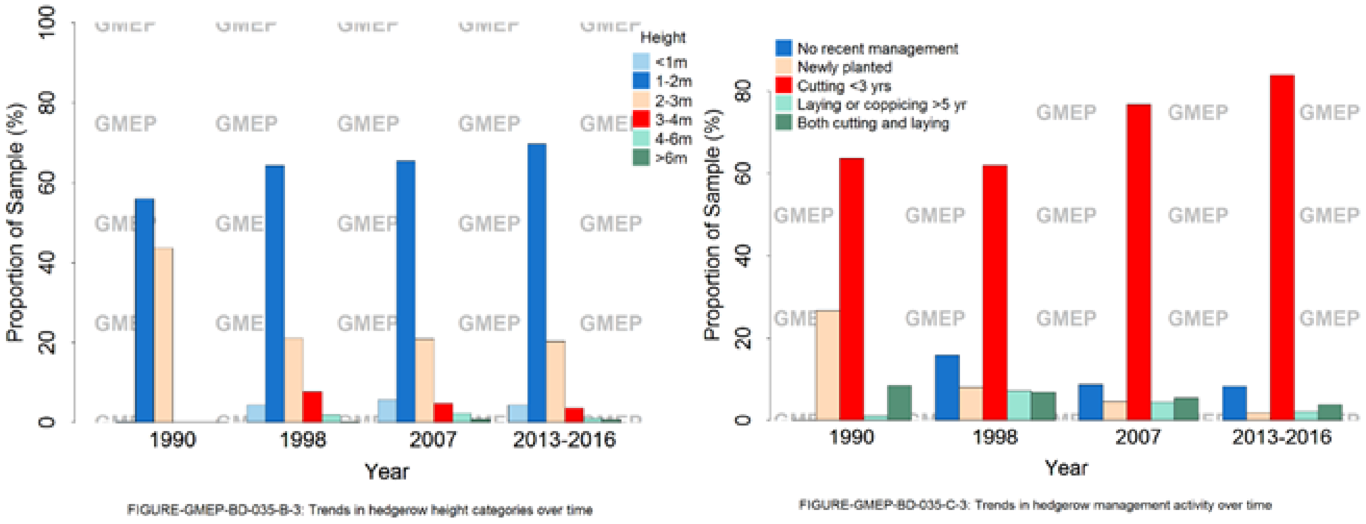


Figure 4.2.3. Trends in a) Hedgerow height, b) Trends in hedgerow management from hedgerow mapping data

Table 4.2.3. *Trends in Hedgerow width 2007-2016 (calculated using woody diversity plots)*

Width	2007	2016
	% of plots	
<1 m	3.9	3.3
1-1.5 m	22.9	17.8
1.5-2 m	26.8	28
2-2.5 m	21.1	19.7
2.5-3 m	12.4	13.8
3.0-4.0 m	7.6	10.7
4.0-5.0 m	5.3	6.7

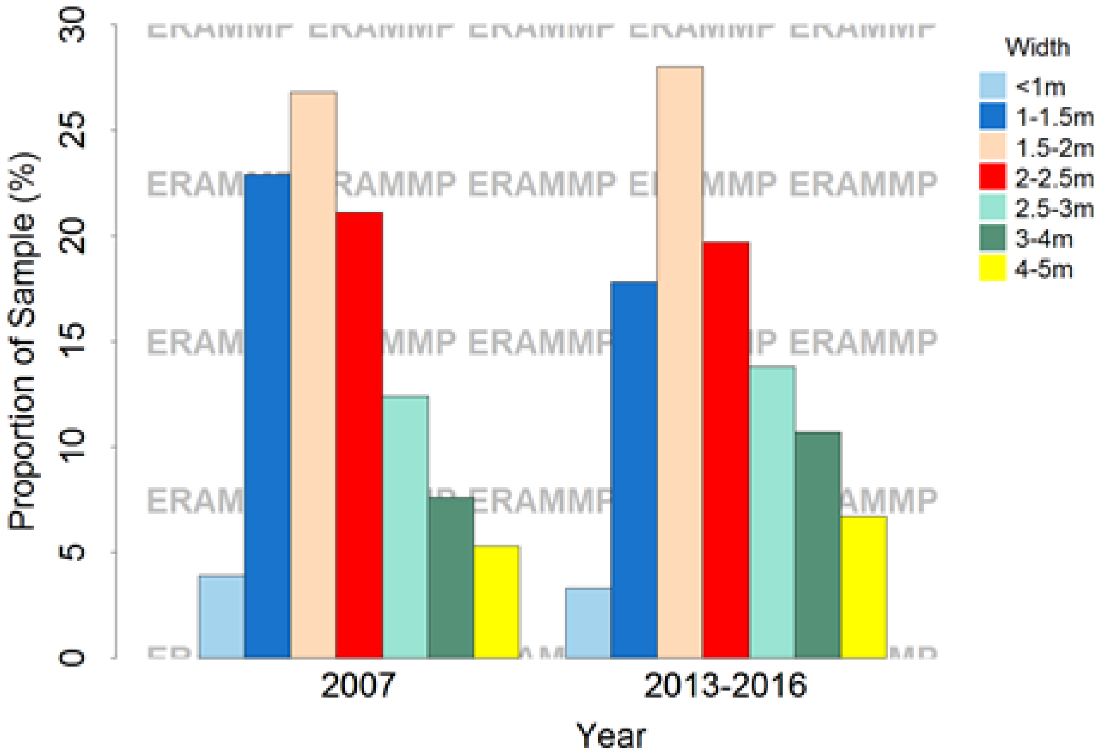


Figure 4.2.4. Trends in hedgerow width categories over time 2007-2016 (calculated using woody diversity plots)

Table 4.2.4. *Trends in Hedgerow width categories 2000-2016 (calculated using woody diversity plots)*

Width	2000	2007	2016
	% of plots		
< 1 M	10.2	3.9	3.3
1 - 2 M	76.3	49.7	45.8
> 2 M	12.9	46.3	50.7

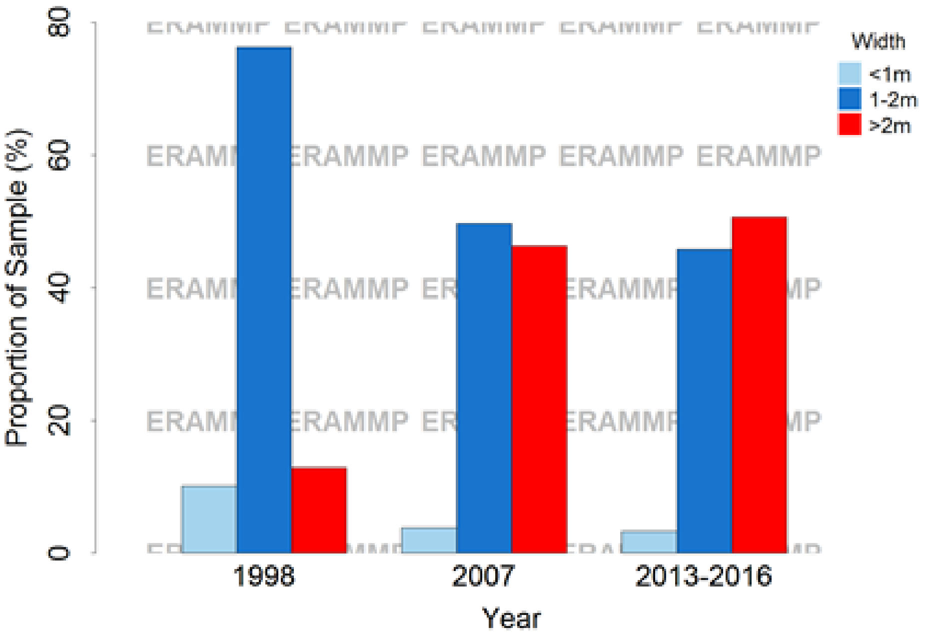


Figure 4.2.5. Trends in hedgerow width categories over time 2016 (calculated using woody diversity plots)

Table 4.2.5. *Trends in hedgerow woody species richness over time. "↔" represents non-significance in a trend, indicating stability and/or low sample size.*

Year	Mean spp diversity	Lower_est.	Upper_est.	Trend
1998	5.83	5.50	6.16	↔ 1998-2016 ns
2007	6.70	6.45	6.96	↑ 1998-2007***
2016	5.39	5.19	5.60	↓ 2007-2016***

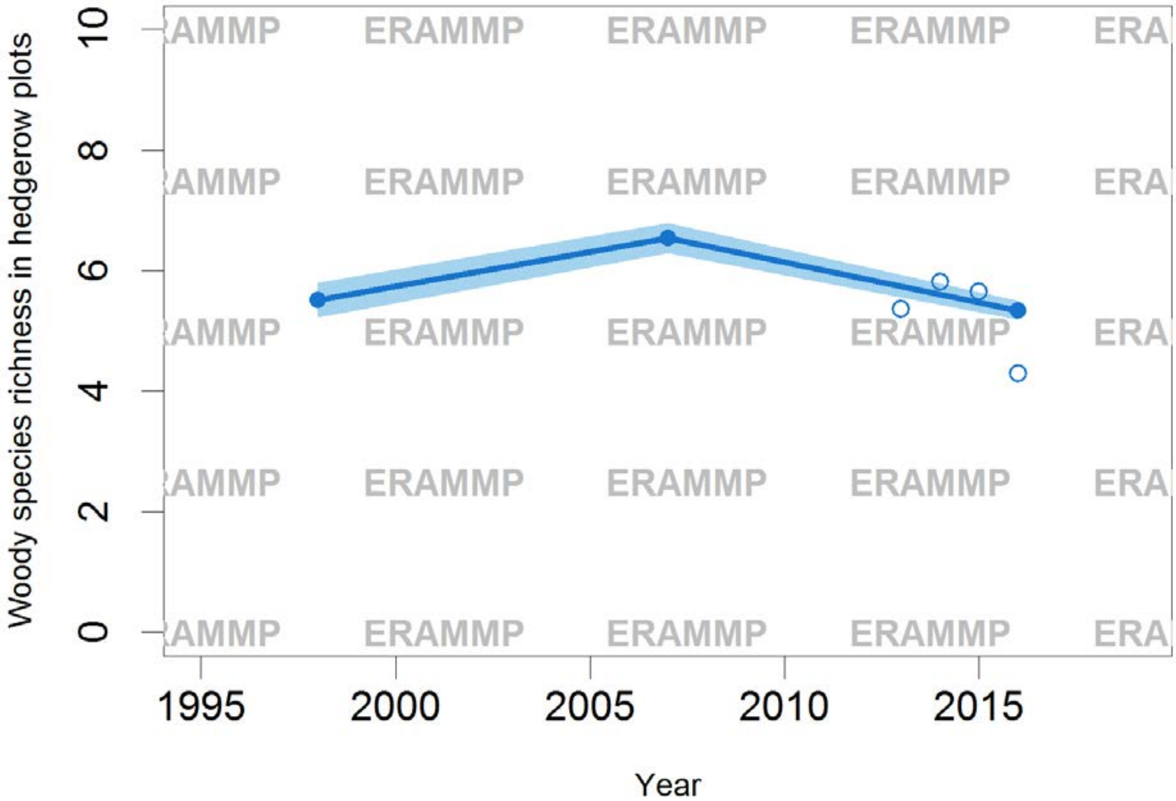


Figure 4.2.6. Trends in woody species richness in hedgerow plots over time

Table 4.2.6. *Trends in Hedgerow ground flora species richness over time (negative indicator species Urtica dioica, Rumex sp., Galium aparine, Poa annua, Cirsium arvense, Cirsium vulgare, Bromus hordeaceus, Seneco vulgaris and Stellaria media* removed from analysis*). "↔" represents non-significance in a trend, indicating stability and/or low sample size.*

Year	Mean spp diversity	Lower_est.	Upper_est.	Change
1990	18.2	16.6	19.7	↔ ns
1998	18.2	16.9	19.5	↔ ns
2007	16.5	15.6	17.4	↔ ns
2016	20.0	19.2	20.9	↑ 2007-2016 ***

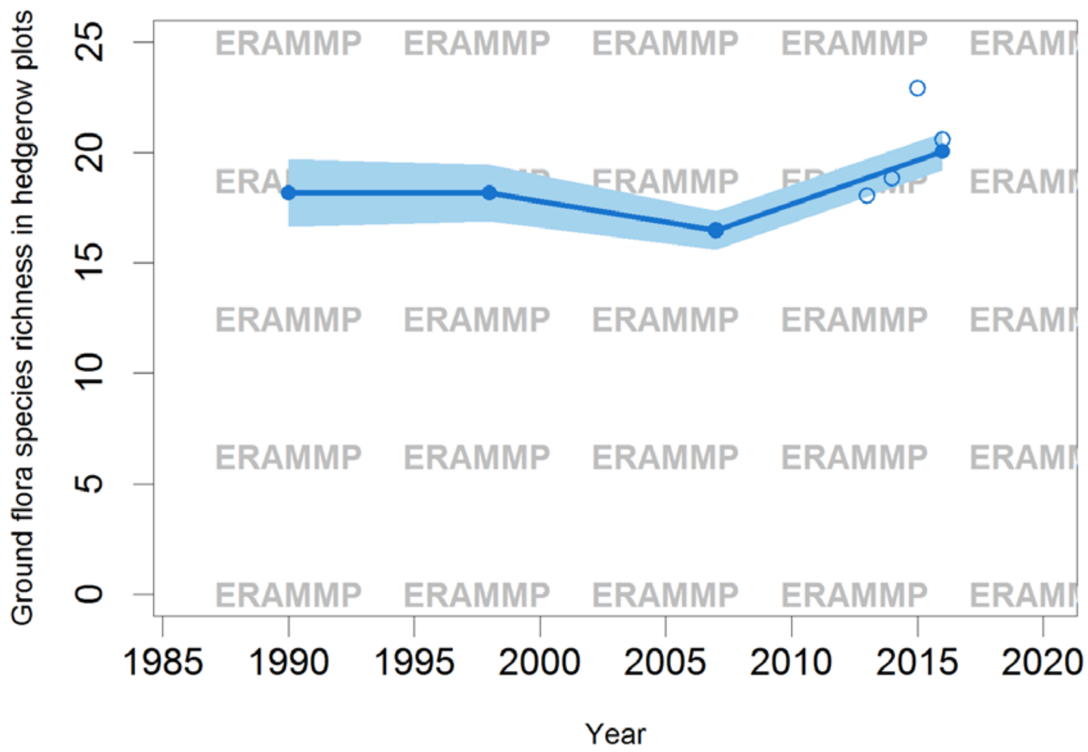


Figure 4.2.7. Changes in ground flora species richness over time (calculated using hedgerow plots and boundary plots where the boundary is a hedgerow).

Table 4.2.7. The percentage of plots where cover of docks (Rumex sp.), Cleavers (Galium aparine) and nettles (Urtica dioica) is greater than 20%, indicating eutrophication

	2007	2016
% of plots	16.3	25.6

Table 4.2.8. National estimates of the trends in the extent of Woody linear features

	Year	Estimate	Lower	Upper
Total	1990	107.59	92.36	117.90
	1998	114.30	99.56	124.41
	2007	121.89	107.95	131.29
	2016	120.11	105.51	131.23
WUS (Hedgerows)	1990	69.83	59.51	78.49
	1998	65.04	55.15	73.29
	2007	65.43	56.97	73.54
	2016	61.67	52.18	68.90
WNS (Lines of trees)	1990	36.00	28.50	43.47
	1998	47.62	40.66	54.97
	2007	54.99	48.52	60.76
	2016	59.36	50.99	65.01

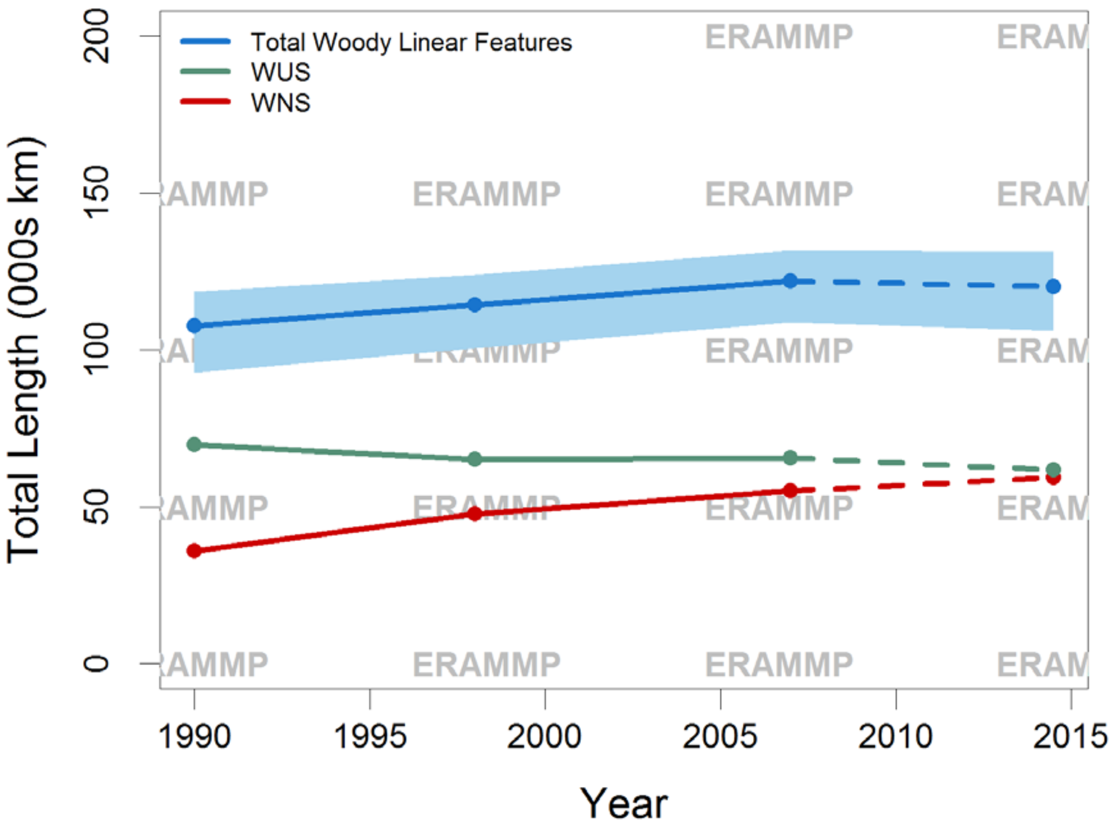


Figure 4.2.8. Trends in length of woody linear features (calculated using field mapping data)

4.2.3 Discussion

Management changes are rather mixed. There were some increases in the <3 yearly cutting of hedges, and some decreases in the numbers of hedges which have been laid or laid and cut. Height of base of canopy measures also indicate a decrease in the traditional management of hedges. Traditional management of hedgerows, hedgerow laying, would result in a base of canopy <0.5m. For hedge regeneration <3 yearly hedge cutting needs to be part of a longer cycle of hedge laying (>20 yearly).

The height profiles of mapped hedges in 2007 were broadly similar to those in 2016, however measures in the Hedge Diversity plots indicate an increase in the width of hedges (from 1998 but slightly greater in 2016). The wider hedgerows contribute to increases in the proportion of plots in good structural condition, if the base height was not increasing at the same time there would be even more plots in good condition. Keenleyside et al. (2019) suggest that a lack of incentives to promote regeneration of trees in hedgerows (through laying) leads to trees growing on to become hedgerow trees and the increase in base height could be associated with this.

Active hedgerow management including laying and coppicing is included in the Glastir advanced hedgerow management option which should be an incentive. The decrease in laying and coppicing could be associated with a decline in traditional hedgerow management skills (Keenleyside et al. 2019).

There appears to have been a decrease in woody species diversity.

Species richness of the hedgerow ground flora was higher in 2016, although not higher than earlier years (1990 and 1998) it may reflect a recovery from a dip in 2007.

There has been no significant change in the lengths of woody linear features overall although potentially trends towards decreasing hedgerow length and increasing length of lines of trees (not statistically significant). The figures presented are slightly different to those in the CS 2007 report due to the consistent estimation modelling approach (although the results do fall within the confidence limits given previously). There has been increased information in recent years from larger sample sizes, in 1990 estimates were based on 47 squares, 1998- 64, 2007 107 and GMEP 150) Options for new hedgerow planting under Glastir may not be reflected in this data from 2016.

4.3 State: Trees and clover in improved and semi-improved grasslands

The GMEP final report did not present information on the cover or frequency of trees or clover (*Trifolium repens* and *T. pratense*) on improved land in Wales. The former is of interest to begin to understand the extent of wood pasture and wood parkland across Wales. The latter is of interest to ascertain the current prevalence of key legumes in improved and semi-improved swards across Wales.

4.3.1 Methods

Mapping surveys

Habitat areas (>20m x 20m) were mapped in each GMEP square and classified using the Broad and Priority Habitat classification (BRIG and Maddock 2008). Additional attributes were recorded using a comprehensive range of pre-determined options which relate directly to Broad and Priority Habitats, vegetation types and landscape features (e.g. Agriculture, Forestry, Buildings and structures); supporting attribute data (e.g. grass ley, burnt vegetation), indicative species presence and cover; and land usage (e.g. stock, cattle, sheep, timber production).

Point features were also mapped in each square, representing individual landscape elements that occupy less than an area of 20x20m. They include: forestry features such as individual trees, clumps of trees, patches of scrub, veteran trees; inland water features such as springs and ponds; inland physiography such as cliffs and rocky outcrops and structures such as buildings, quarries and wind turbines. Additional attributes are also recorded for individual point features. For more information on GMEP square selection and mapping methodology, see the GMEP reports and appendices https://gmep.wales/.

Data analysis

We extracted data about all parcels identified as “improved grassland” or “neutral grassland” (i.e. semi-improved grassland – most neutral grassland in wider Wales cannot be classified as semi-natural grassland) visited during field visits to 300 1km squares from 2013-2016. This includes data from 150 “wider Wales” squares which are a stratified-random sample of Wales’ countryside, as well as 150 “targeted component” squares which are targeted based on various criteria linked to Glastir agri-environmental payments.

As well as attributes of parcels, including information on scattered trees and species cover, we extracted the number of trees and/or clumps of trees recorded more than 3m from the edge of each parcel. For improved and semi-improved grasslands, we placed large (>1ha) and small (<1ha) land parcels into categories based on (1) the frequency of individual trees (none, 2-5, 6+ or wood parkland) and (2) the presence or absence of clumps of trees.

We also summarise the area of improved and semi-improved grassland falling into different cover categories for white clover *Trifolium repens* and red clover *T. pratense*. When surveyors mapped an area of improved or neutral grassland, they record cover of up to four dominant or characteristic species. As such, where a species has low cover is it unlikely to be recorded. Thus, the results presented here should be taken as a conservative impression of the frequency of clover in improved and semi-improved grassland.

4.3.2 Results

Trees were absent across the vast majority of improved and semi-improved fields that were surveyed across Wales (Figures 4.3.1-4, Tables 4.3.1-4). Semi-improved fields contained trees more often than improved fields, while larger fields contained trees more often than small fields; trees were present within ~10% of small improved fields, but ~26% of large, semi-improved fields. Where trees were present, they usually comprised 2-5 individual trees, or sometimes at least one clump of trees within the field (Figures 4.3.1-4, Tables 4.3.1-4).

Trifolium repens was mostly present on improved grassland, but mostly absent or not recorded on semi-improved grassland (Figures 4.3.5-6, Tables 4.3.5-6). Where present, it mostly occurred at 10-25% cover on both grassland types. *Trifolium pratense* was almost always absent on improved grassland (Figure 4.3.7, Table 4.3.7). However, it did occur on 9% of semi-improved grassland fields, usually at <10% cover (Figure 4.3.8, Table 4.3.8).

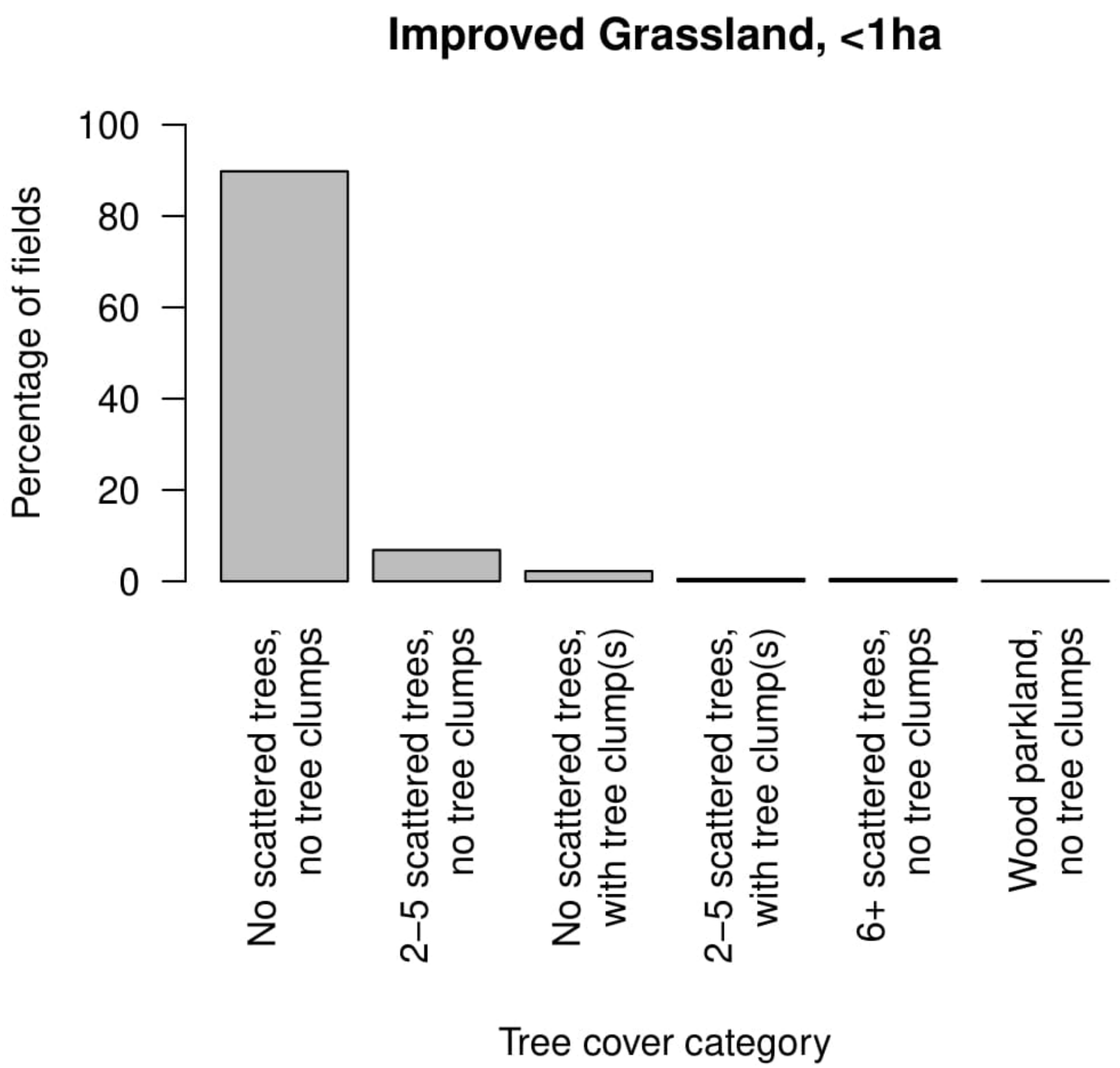


Figure 4.3.1. *Percentage of small (less than 1ha) improved grassland fields in different categories based on presence and frequency of trees in 2016.*

Table 4.3.1. *Numbers and percentage of small (less than 1ha) improved grassland fields in different categories based on presence and frequency of trees in 2016.*

Individual trees	Clumps of trees	Number of fields	Percent of total
No scattered trees	no tree clumps	1207	89.81
2-5 scattered trees	no tree clumps	92	6.85
No scattered trees	with tree clump(s)	30	2.23
2-5 scattered trees	with tree clump(s)	7	0.52
6+ scattered trees	no tree clumps	7	0.52
Wood parkland	no tree clumps	1	0.07

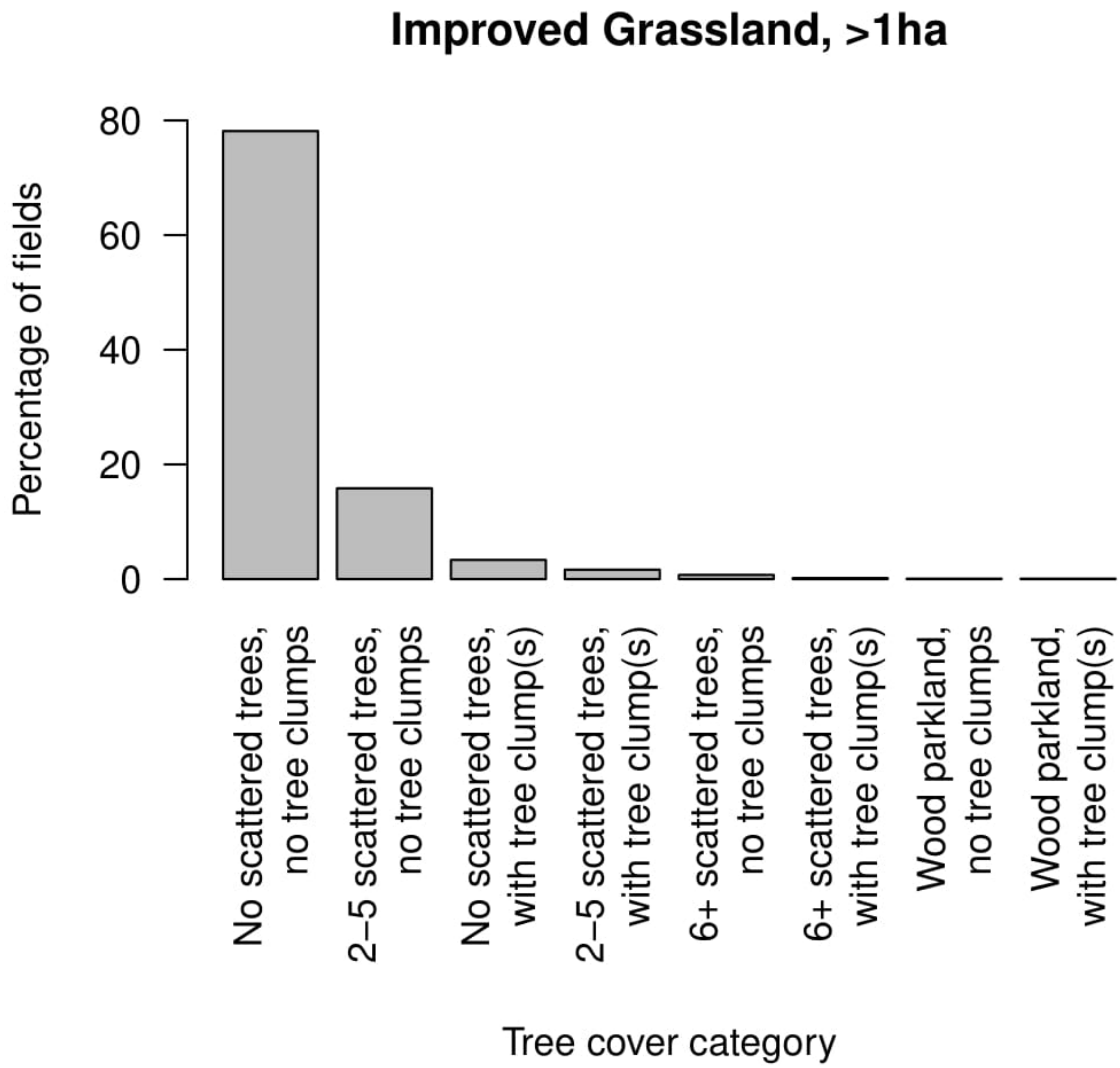


Figure 4.3.2. *Percentage of large (more than 1ha) improved grassland fields in different categories based on presence and frequency of trees in 2016.*

Table 4.3.2. *Numbers and percentage of large (more than 1ha) improved grassland fields in different categories based on presence and frequency of trees in 2016.*

Individual trees	Clumps of trees	Number of fields	Percent of total
No scattered trees	no tree clumps	1283	78.14
2-5 scattered trees	no tree clumps	260	15.83
No scattered trees	with tree clump(s)	55	3.35
2-5 scattered trees	with tree clump(s)	27	1.64
6+ scattered trees	no tree clumps	12	0.73
6+ scattered trees	with tree clump(s)	3	0.18
Wood parkland	no tree clumps	1	0.06
Wood parkland	with tree clump(s)	1	0.06

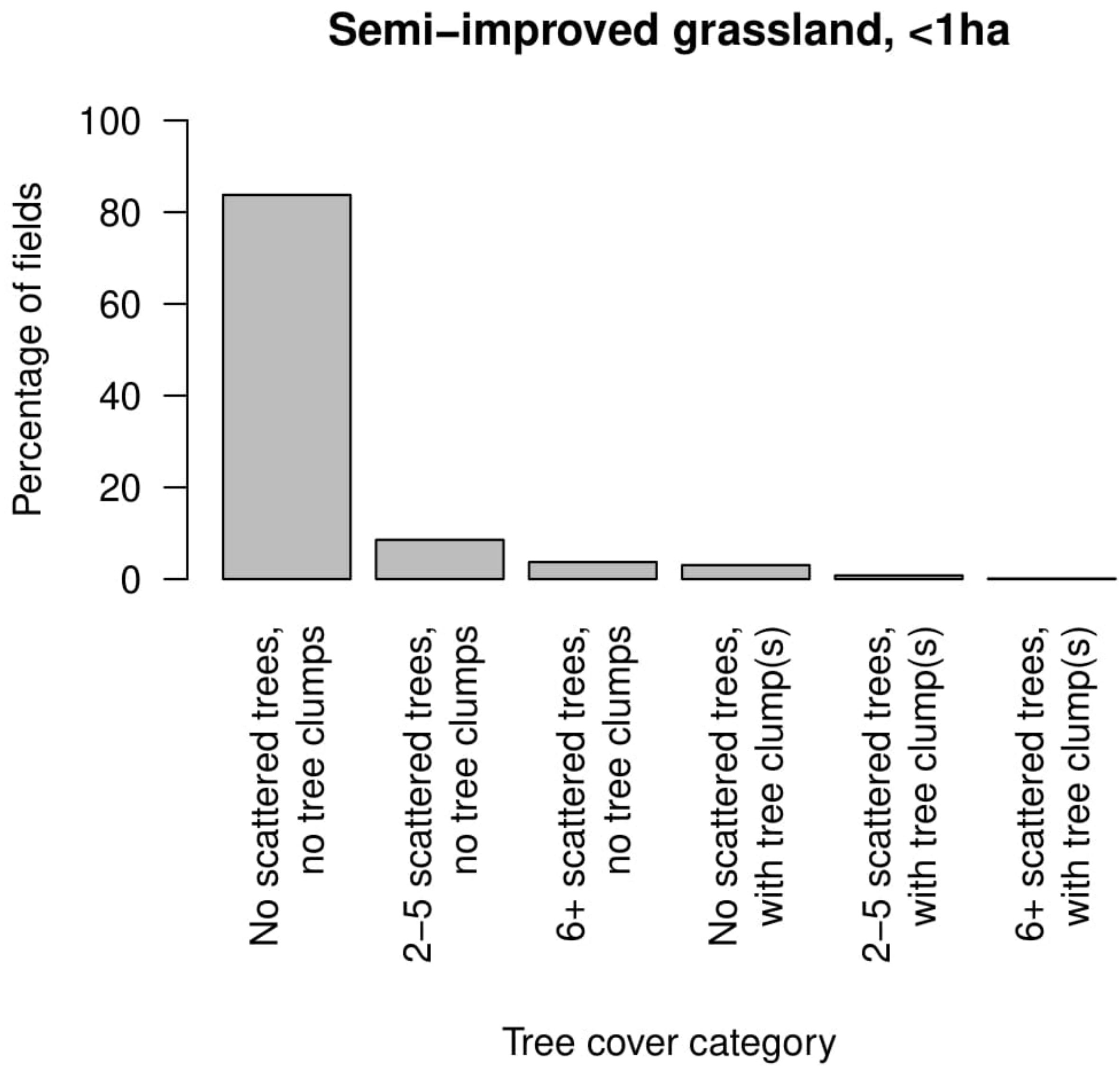


Figure 4.3.3. *Percentage of small (less than 1ha) semi-improved grassland fields in different categories based on presence and frequency of trees in 2016.*

Table 4.3.3. *Numbers and percentage of small (less than 1ha) semi-improved grassland fields in different categories based on presence and frequency of trees in 2016.*

Individual trees	Clumps of trees	Number of fields	Percent of total
No scattered trees	no tree clumps	2093	83.75
2-5 scattered trees	no tree clumps	214	8.56
6+ scattered trees	no tree clumps	93	3.72
No scattered trees	with tree clump(s)	76	3.04
2-5 scattered trees	with tree clump(s)	20	0.80
6+ scattered trees	with tree clump(s)	3	0.12

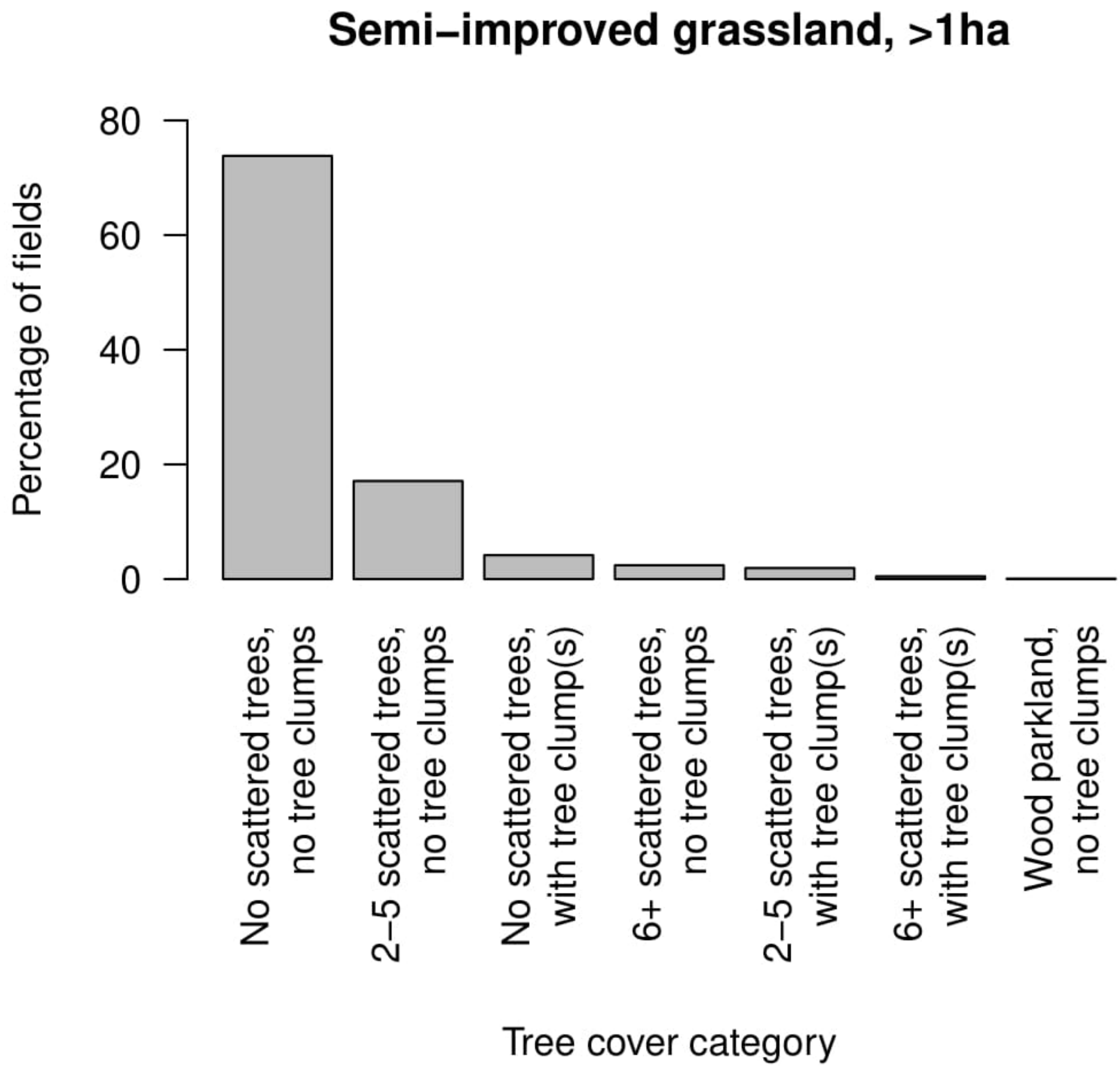


Figure 4.3.4. *Percentage of large (more than 1ha) semi-improved grassland fields in different categories based on presence and frequency of trees in 2016.*

Table 4.3.4. *Numbers and percentage of large (more than 1ha) semi-improved grassland fields in different categories based on presence and frequency of trees in 2016.*

Individual trees	Clumps of trees	Number of fields	Percent of total
No scattered trees	no tree clumps	919	73.82
2-5 scattered trees	no tree clumps	213	17.11
No scattered trees	with tree clump(s)	52	4.18
6+ scattered trees	no tree clumps	30	2.41
2-5 scattered trees	with tree clump(s)	24	1.93
6+ scattered trees	with tree clump(s)	6	0.48
Wood parkland	no tree clumps	1	0.08

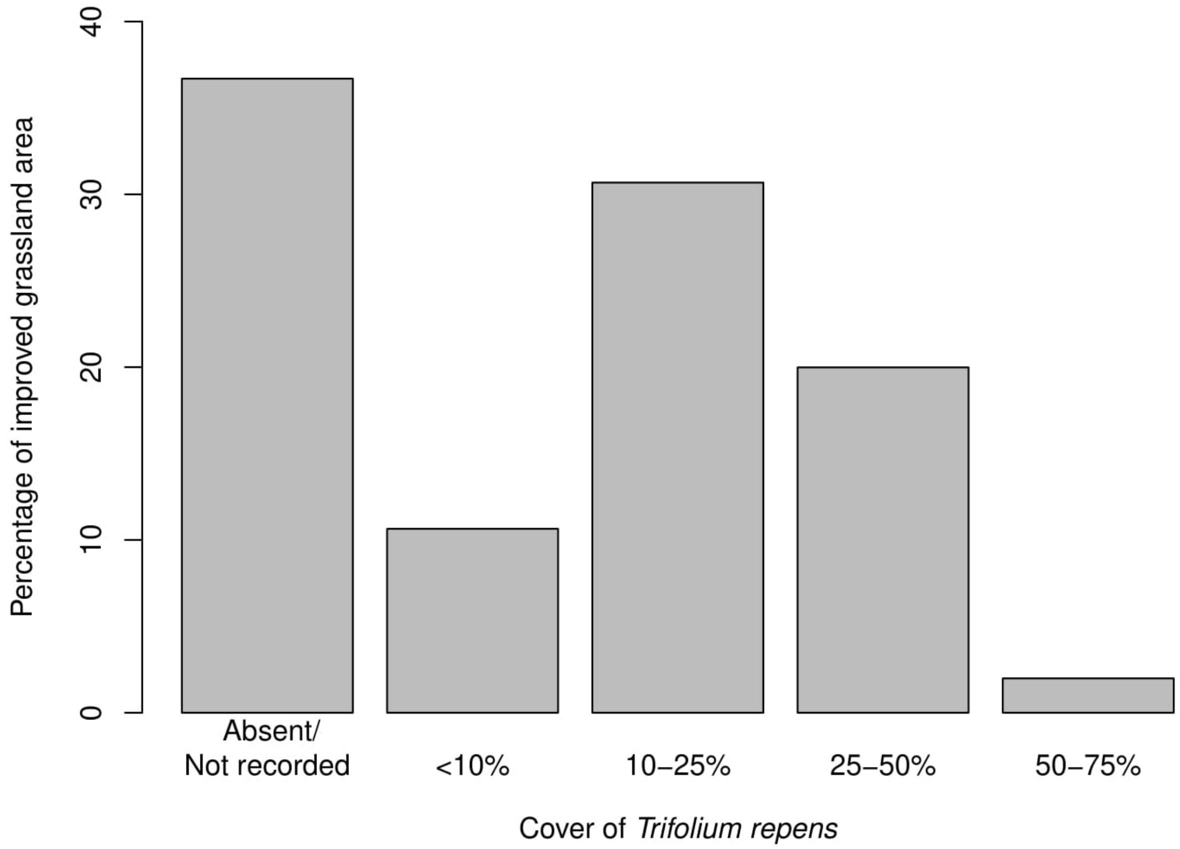


Figure 4.3.5. *Percentage area of improved grassland falling into different categories based on cover of white clover* Trifolium repens*.*

Table 4.3.5. *Area and percentage area of improved grassland falling into different categories based on cover of white clover* Trifolium repens *in 2016.*

***Trifolium repens* cover**	**Area (ha)**	**Percentage area**
Absent/not recorded	1794.57	36.70
<10%	520.63	10.65
10-25%	1500.40	30.68
25-50%	977.43	19.99
50-75%	97.29	1.99

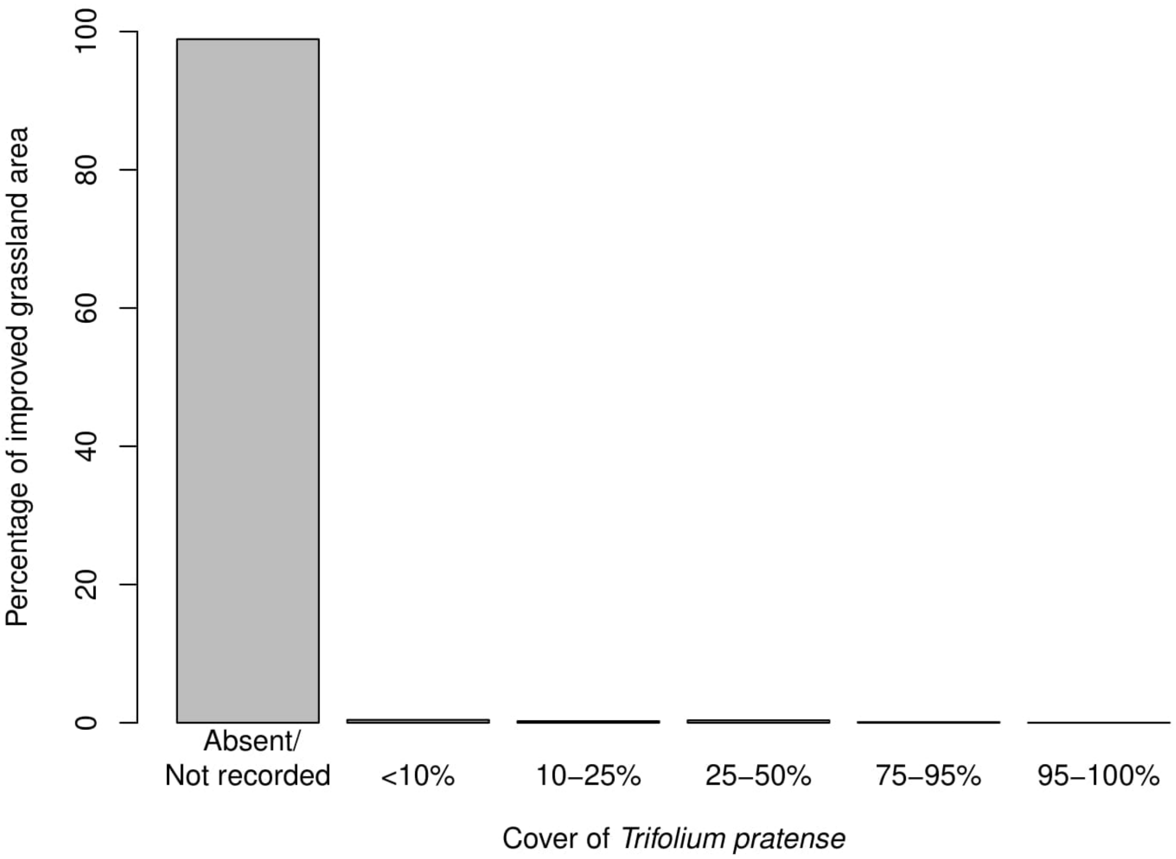


Figure 4.3.6. *Percentage area of improved grassland falling into different categories based on cover of white clover* Trifolium pratense *in 2016.*

Table 4.3.6. *Area and percentage area of improved grassland falling into different categories based on cover of white clover* Trifolium pratense *in 2016.*

***Trifolium pratense* cover**	**Area (ha)**	**Percentage area**
Absent/not recorded	4836.44	98.90
<10%	20.12	0.41
10-25%	11.31	0.23
25-50%	17.51	0.36
75-95%	4.62	0.09
95-100%	0.32	0.01

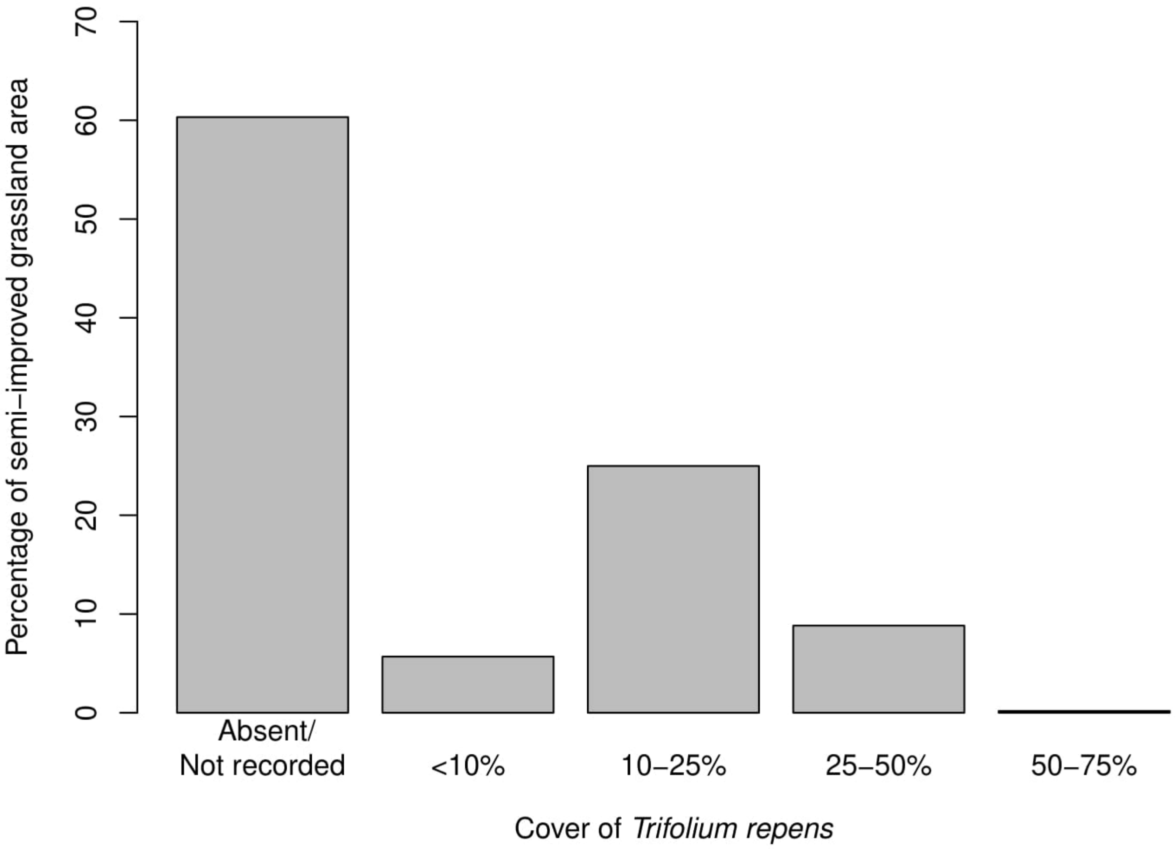


Figure 4.3.7. *Percentage area of semi-improved grassland falling into different categories based on cover of white clover* Trifolium repens *in 2016.*

Table 4.3.7. *Area and percentage area of semi-improved grassland falling into different categories based on cover of white clover* Trifolium repens *in 2016*.

***Trifolium repens* cover**	**Area (ha)**	**Percentage area**
Absent/not recorded	2351.65	60.32
<10%	221.71	5.69
10-25%	974.18	24.99
25-50%	344.05	8.83
50-75%	6.96	0.18

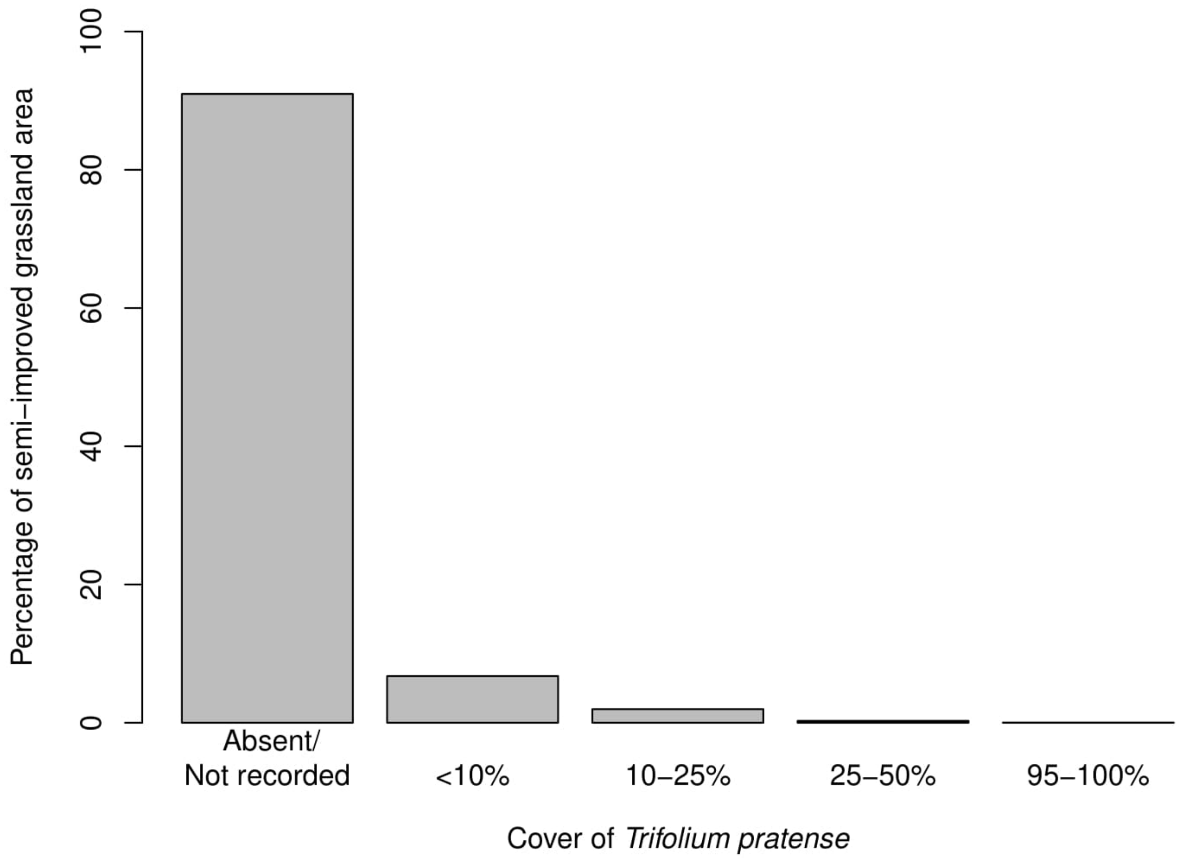


Figure 4.3.8. *Percentage area of semi-improved grassland falling into different categories based on cover of white clover* Trifolium pratense *in 2016.*

Table 4.3.8. *Area and percentage area of semi-improved grassland falling into different categories based on cover of white clover* Trifolium pratense *in 2016*.

***Trifolium pratense* cover**	**Area (ha)**	**Percentage area**
Absent/not recorded	3546.93	90.98
<10%	263.31	6.75
10-25%	76.73	1.97
25-50%	10.64	0.27
95-100%	0.94	0.02

4.3.3 Discussion

These results show that in general, most improved and semi-improved grasslands do not contain trees. Many trees are present on the boundaries between fields (e.g. hedgerow trees) but these are not the focus of the present analysis. They also show that where present, trees tend to occur at a density of 2-5 trees per field. Very few fields were specifically recorded as wood parkland by surveyors. Depending on the definition, it is possible that a non-negligible proportion (e.g. ~5% of large, semi-improved grassland fields containing >6 trees each) of farmed grasslands in Wales could be considered wood pasture.

We also quantify how white clover *Trifolium repens* dominates on improved grassland and occurs frequently on semi-improved grassland. Red clover *T. pratense* is found to be rare – especially on improved grassland fields. These numbers, obtained from mapping data, represent a conservative estimate of the relative cover of these two species. This is because although all species were recorded during vegetation surveys, only three to four dominant species were recorded during mapping of habitat areas. Legumes are of particular interest on enclosed farmland because of their potential to increase soil carbon (Smith et al. 2008) and provide for pollinators (Rundlöf et al. 2014) while maintaining or improving agricultural yield with reduced use of inorganic fertilisers. For *T. pratense* the baseline cover across Wales is apparently very low, presumably because it is rarely sown or favoured by grassland management. An opportunity exists to increase *T. pratense* cover through e.g. agri-environment interventions.

5 Analyses for Semi-Natural Grassland

5.1 Trends: Vegetation condition and species richness

The Glastir Monitoring and Evaluation Programme (GMEP) final report presented an analysis of trends in habitat condition of woodland, improved land and "habitat" land (all non-woodland, non-improved land; Emmett and the GMEP team 2017). The report found a recent increase in the condition of habitat land, as measured by (1) total species richness of vascular plants and (2) the richness of species that are positive indicators of any Common Standards Monitoring habitat (https://jncc.gov.uk/our-work/common-standards-monitoring-guidance/). The GMEP "habitat" category included semi-natural grassland (SNG) alongside many other habitat types, so further work was undertaken to produce a trend specific to SNG.

The ERAMMP Report 20 (Maskell et al. 2019a) split the habitat category into SNG (comprising neutral grassland, with less than 25% cover of *Lolium* and *Trifolium*, and acid grassland) and mountain, moor and heath (MMH). This revealed both short and long term increases in condition and species richness of SNG. However, further work was required to isolate trends in SNG without inadvertently including semi-improved grasslands, which are dominant in the countryside in Wales. Furthermore, a breakdown of trends across key grassland types could aid interpretation and facilitate recommendations for conservation.

Here we increase the definition of reporting of condition of SNG in three key ways:

1) We report on separate SNG categories – namely acid grassland and marshy grassland (represented here by purple moor grass and rush pasture priority habitat). There are insufficient data to report condition trends on neutral semi-natural grassland and calcareous grassland, although semi-improved grasslands are now reported under enclosed farmland.
2) For each reporting category, we derive condition as the species richness of positive indicators specifically relevant to that category. Species lists were reviewed and amended by SoNaRR technical leads at NRW to ensure that they were fit for purpose.
3) For each reporting category, in the analysis of overall species richness we remove a specific list of species which are negative indicators for that category. Species lists were reviewed and amended by SoNaRR technical leads at NRW to ensure that they were fit for purpose.

5.1.1 Methods

Vegetation surveys

In each 1km square, plant species presence and cover was recorded in different sizes and types of vegetation plot (Emmett and the GMEP team 2017, Wood et al. 2017). Random points marking the position of five random or 'nested' plots (X plots) in each square were determined prior to the field survey. The locations, type and numbers of other kinds of plot were determined based on a rule-set, using the 'nested' plots as a starting point (or based on other mapping exercises). For more information on GMEP square selection and vegetation sampling methodology, see the GMEP reports and appendices https://gmep.wales/. Three particular plot types are relevant to this report:

1) Nested plots to provide a random sample of common vegetation types (X plots). Only the inner 2x2m area of these plots is used here for consistency across plot types and survey years.
2) Targeted 2x2m plots to sample Priority Habitats and locations eligible for Glastir (Y plots).
3) Unenclosed 2x2m plots to sample unenclosed Broad Habitats (U plots).

Data analysis

For each of two reporting categories (acid grassland and marshy grassland), we extracted the relevant vegetation plots from Countryside Survey (CS) and GMEP surveys. Marshy grassland was represented by plots classified as purple moor grass and rush pasture priority habitat. We included random plots ("X plots") as well as stratified random plots from unenclosed habitats ("U plots") and plots targeted to priority habitats ("Y plots") in the analysis (Wood et al. 2017). We calculated the richness of positive indicator species, and overall vascular plant species richness excluding negative indicators, using to category-specific species lists reviewed by NRW technical leads. Positive and negative species lists for acid grassland and marshy grassland are presented in Annex 5.

We analysed trends in species richness using linear mixed-effects models (LMMs) in the *R* package *nlme* (Pinheiro et al. 2019, R Core Team 2019). Species richness was log-transformed to ensure model residuals resembled a Gaussian distribution. We used a fixed effect for survey year with a correlation structure to account for repeated measures in CS and GMEP surveys

5.1.2 Results

Acid grassland: Condition

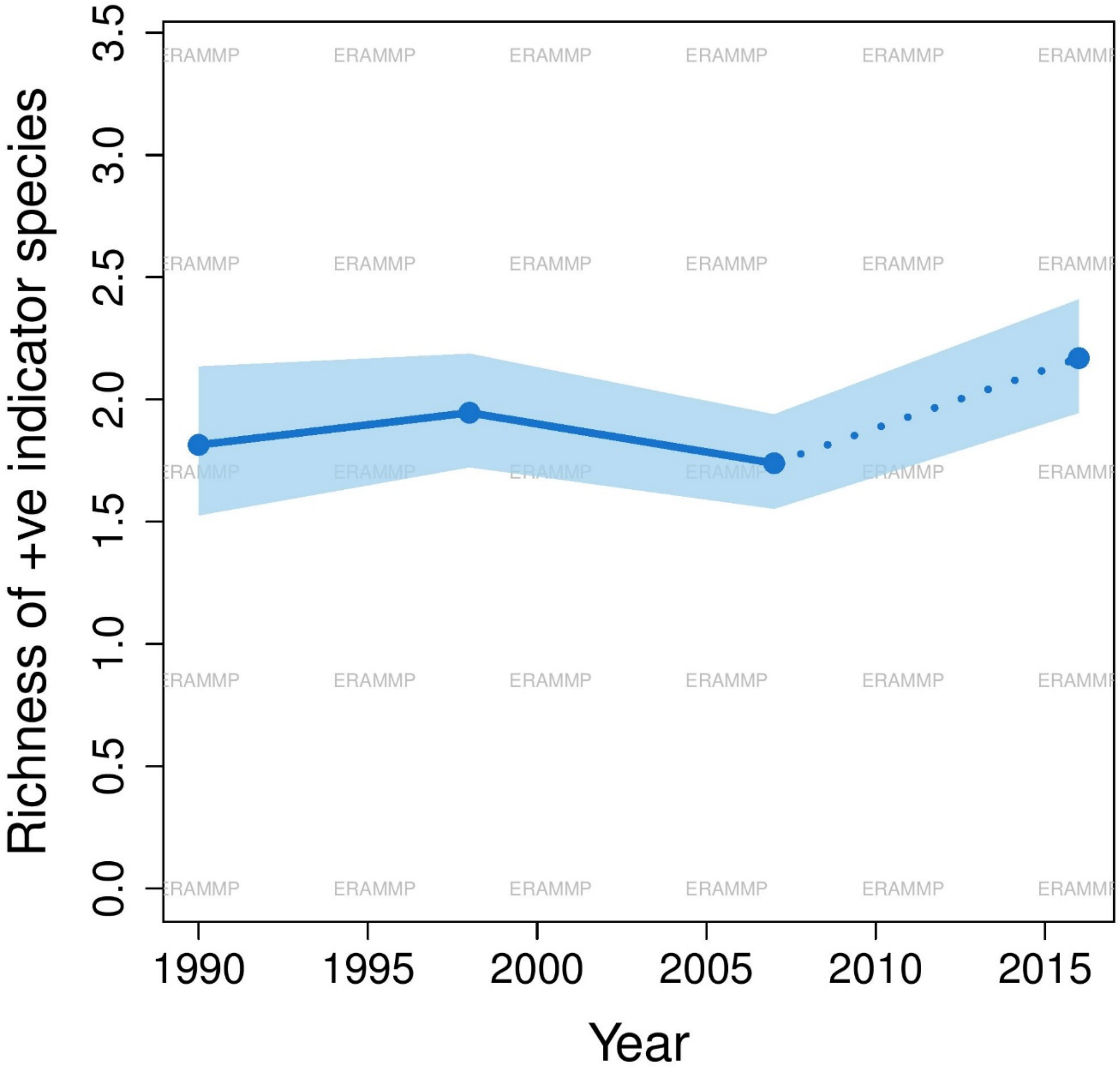


Figure 5.1.1. *Richness of positive indicator species in vegetation plots on acid grassland from 1990-2016. Blue dots represent estimates from a linear mixed-effects model, including year as a fixed effect. The light blue area above and below each estimate represents 95% confidence intervals. Data from 1990-2007 are from Countryside Survey; data from 2016 are from the Glastir Monitoring and Evaluation Programme.*

Table 5.1.1. *Estimates of richness of positive indicator species in vegetation plots on acid grassland from 1990-2016.* P*-values are shown for pairwise comparisons between GMEP 2016 and other survey years. The number of plots included in the analysis for acid grassland is also shown. "↔" represents non-significance in a trend, indicating stability and/or low sample size.*

Year	Species richness estimate	*P*-value vs. 2016	Number of plots	Long-term trend	Short-term trend
1990	1.81	0.07	60	↔	↑
1998	1.95	0.17	128		
2007	1.74	**<0.001**	184		
2016	2.17	NA	184		

Acid grassland: Species richness

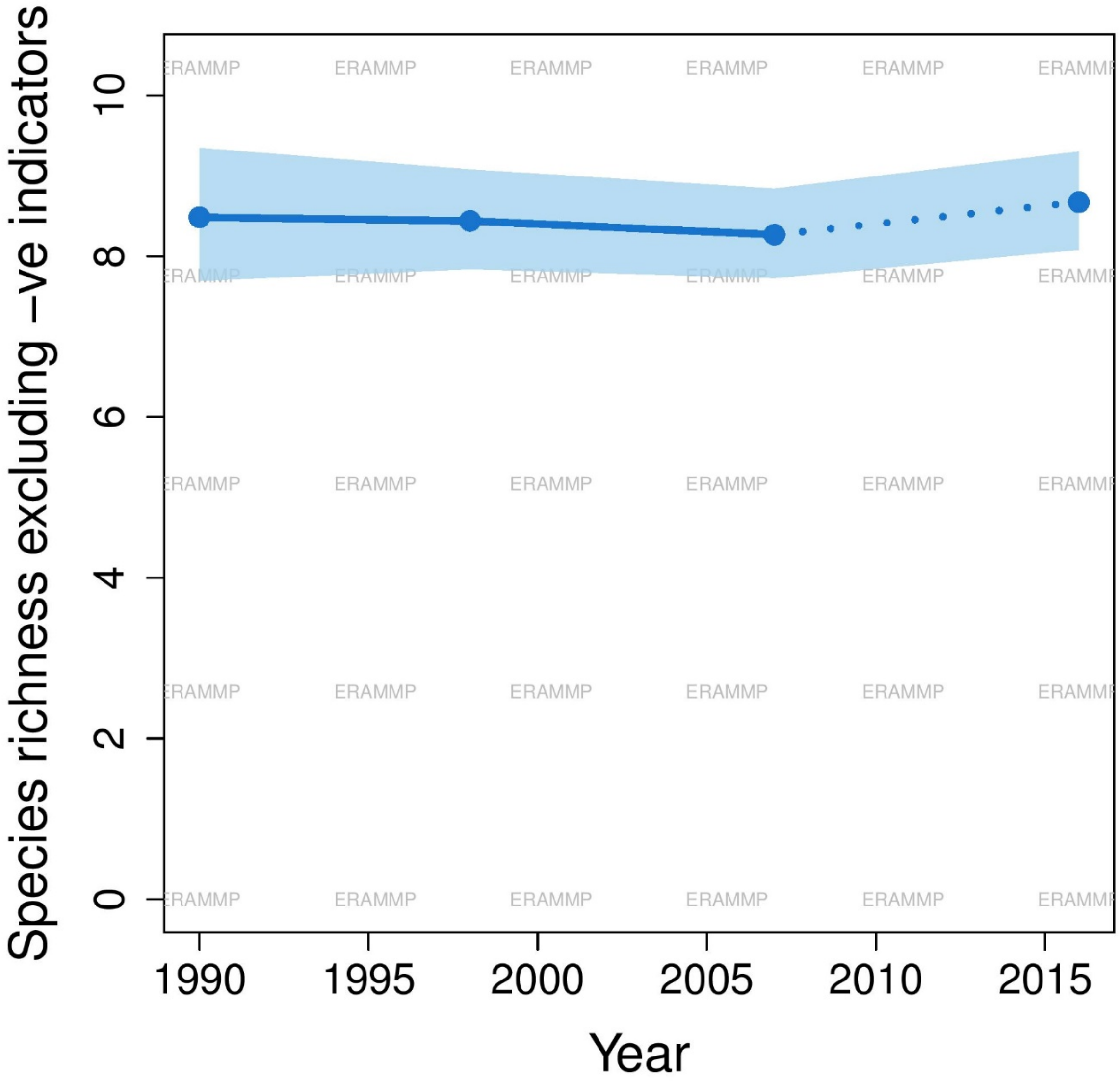


Figure 5.1.2. *Species richness in vegetation plots on acid grassland from 1990-2016 (excluding negative indicator species). Blue dots represent estimates from a linear mixed-effects model, including year as a fixed effect. The light blue area above and below each estimate represents 95% confidence intervals. Data from 1990-2007 are from Countryside Survey; data from 2016 are from the Glastir Monitoring and Evaluation Programme.*

Table 5.1.2. *Estimates of Species richness in vegetation plots on acid grassland from 1990-2016 (excluding negative indicator species).* P*-values are shown for pairwise comparisons between GMEP 2016 and other survey years. The number of plots included in the analysis for acid grassland is also shown. "↔" represents non-significance in a trend, indicating stability and/or low sample size.*

Year	Species richness estimate	*P*-value vs. 2016	Number of plots	Long-term trend	Short-term trend
1990	8.48	0.71	60	↔	↔
1998	8.44	0.58	128		
2007	8.27	0.31	184		
2016	8.67	NA	184		

Marshy grassland: Condition

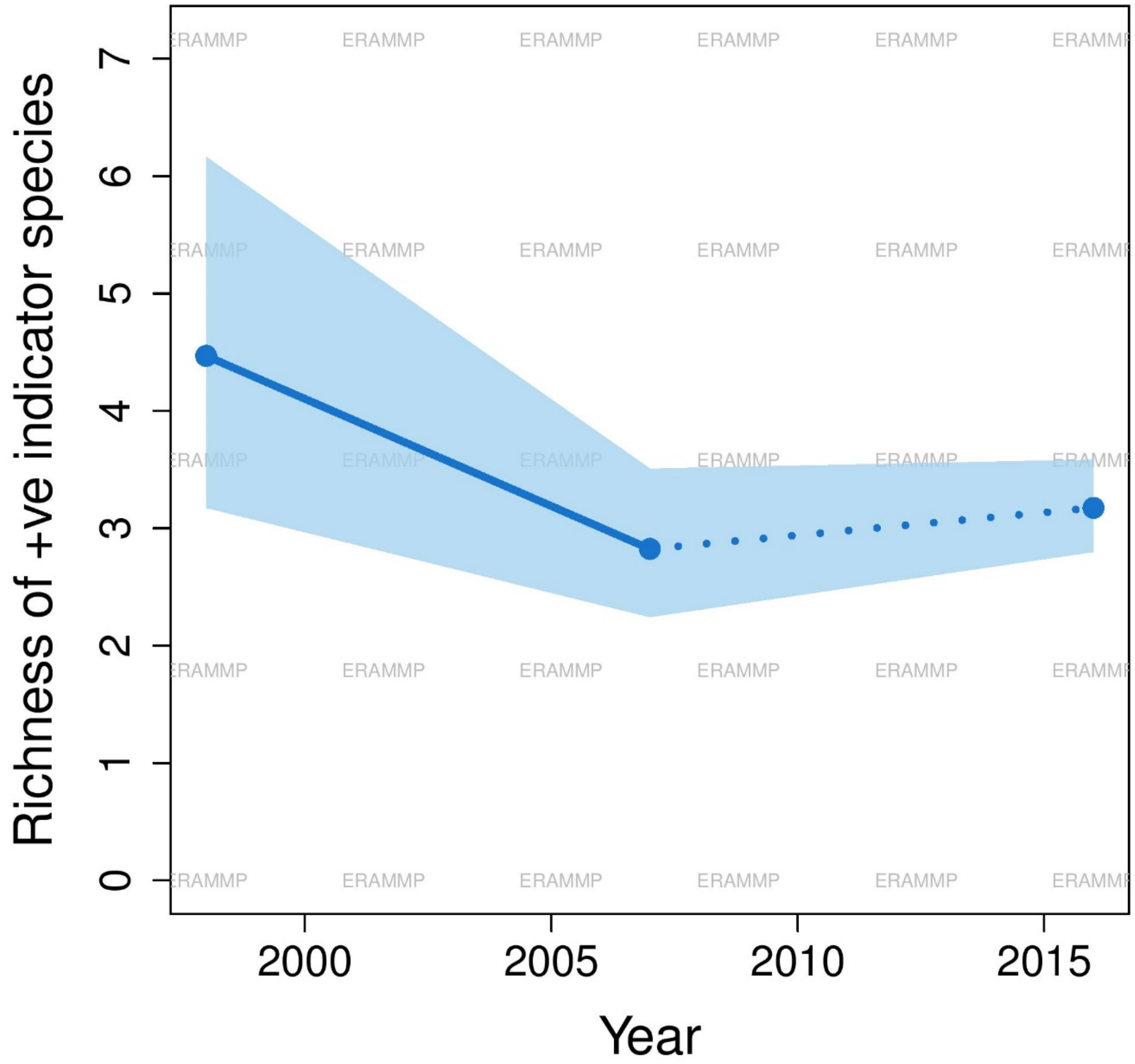


Figure 5.1.3. *Richness of positive indicator species in vegetation plots on marshy grassland from 1990-2016. Blue dots represent estimates from a linear mixed-effects model, including year as a fixed effect. The light blue area above and below each estimate represents 95% confidence intervals. Data from 1990-2007 are from Countryside Survey; data from 2016 are from the Glastir Monitoring and Evaluation Programme.*

Table 5.1.3. *Estimates of richness of positive indicator species in vegetation plots on marshy grassland from 1998-2016.* P*-values are shown for pairwise comparisons between GMEP 2016 and other survey years. The number of plots included in the analysis for marshy grassland is also shown. "↔" represents non-significance in a trend, indicating stability and/or low sample size.*

Year	Species richness estimate	*P*-value vs. 2016	Number of plots	Long-term trend	Short-term trend
1998	4.47	0.13	5	↔	↔
2007	2.82	0.39	30		
2016	3.17	NA	108		

Marshy grassland: Species richness

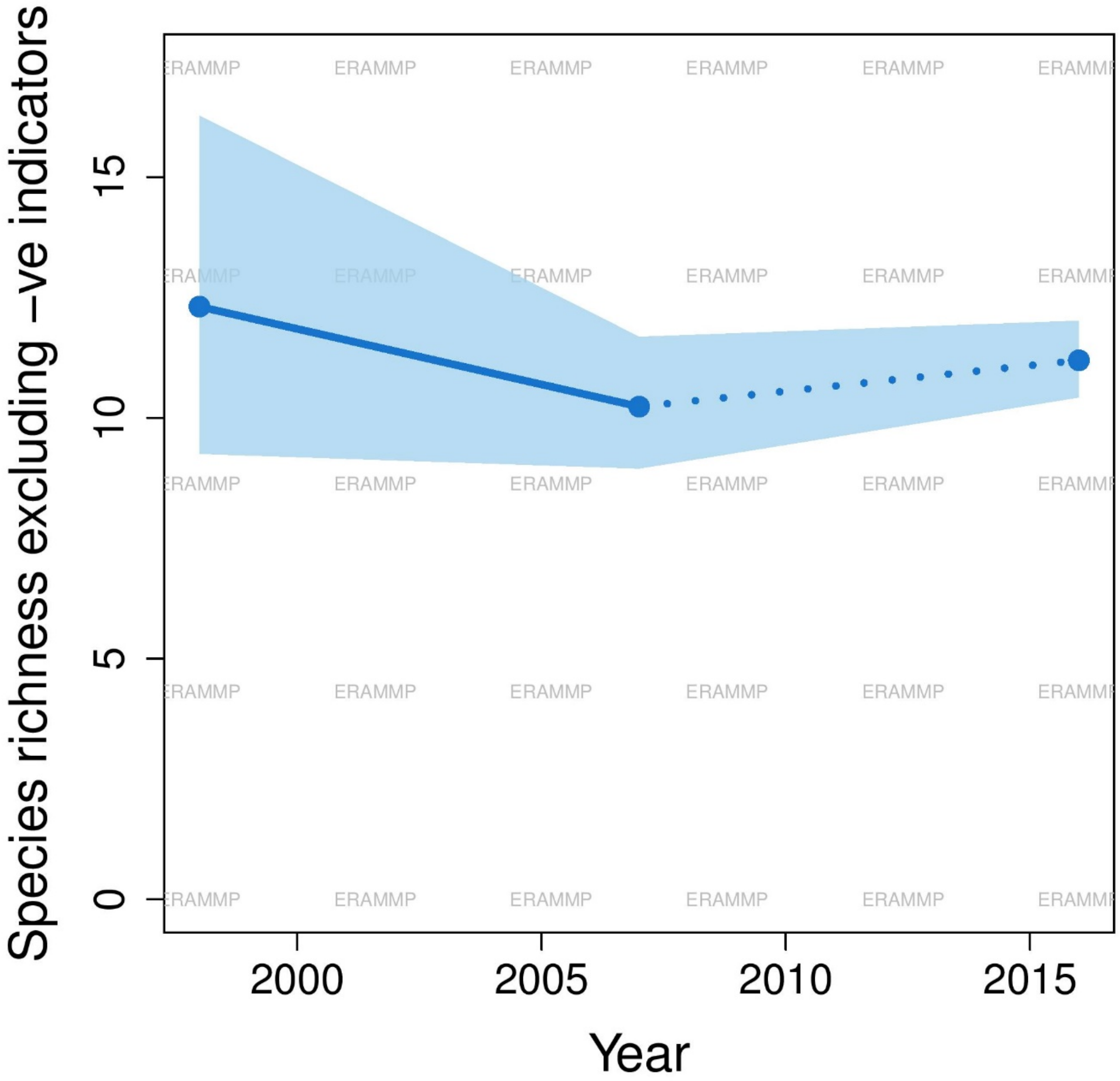


Figure 5.1.4. *Species richness in vegetation plots on marshy grassland from 1990-2016 (excluding negative indicator species). Blue dots represent estimates from a linear mixed-effects model, including year as a fixed effect. The light blue area above and below each estimate represents 95% confidence intervals. Data from 1990-2007 are from Countryside Survey; data from 2016 are from the Glastir Monitoring and Evaluation Programme.*

Table 5.1.4. *Estimates of Species richness in vegetation plots on marshy grassland from 1998-2016 (excluding negative indicator species).* P*-values are shown for pairwise comparisons between GMEP 2016 and other survey years. The number of plots included in the analysis for marshy grassland is also shown. "↔" represents non-significance in a trend, indicating stability and/or low sample size.*

Year	Species richness estimate	*P*-value vs. 2016	Number of plots	Long-term trend	Short-term trend
1998	12.31	0.56	5	↔	↔
2007	10.23	0.30	30		
2016	11.20	NA	108		

5.1.3 Discussion

These results reveal trends in the condition of SNG in Wales at a higher definition than has been previously reported.

Positive outcomes / improvements

There was a significant increase in the richness of positive indicator species on acid grassland between 2007 and 2016 (Fig. 5.1.1, Table 5.1.1). However, this was not necessarily indicative of a longer term trend, with acid grassland condition in 2016 being not much higher than the corresponding estimate for 1998.

Overall, CS and GMEP data suggest that condition and species richness of SNG has been stable across Wales during recent decades.

Areas for concern

The estimate of marshy grassland condition declines non-significantly from 1998 to 2007, with only 5 relevant plots in Wales in CS 1998.

Comments on the analytical method

The previously reported trend for SNG suggested short and long-term increases in condition and species richness of SNG (Maskell et al. 2019a). While marshy grassland was not included in that trend, acid grassland formed a major component of it. Long term increases may not have been observed here for acid grassland because: (1) the sample size and statistical power are reduced after excluding neutral grassland, (2) neutral (mostly semi-improved) grassland was critical in underpinning the previously reported trend and (3) trends are different for species in category-specific species lists than for species in the generic list used previously (in the past, species that were positive indicators of any Common Standards Monitoring habitat were counted as positive indicators for all reporting categories).

Calcareous grassland condition and species richness could not be analysed; there were no valid plots in Wales in CS 1990 or 1998. Furthermore, there were only 3 valid plots in CS 2007, and 3 valid plots in GMEP 2016. The small amount of neutral grassland that can be confidently considered to be “semi-natural” as opposed to “semi-improved” is addressed in section 5.2 of this report.

5.2 State: Vegetation condition of unimproved, semi-natural neutral grassland

Here we identify fixed point quadrats recorded in Countryside Survey (Wood et al. 2017) and GMEP that are representative of unimproved neutral grassland in Wales. We evaluate their use for assessment of change in condition over time. For each quadrat we calculated richness of positive indicator species determined by SoNaRR technical leads at NRW and examine how these counts have changed over time.

5.2.1 Methods

Quadrats were all 2x2m in area and were selected from the Countryside Survey database for the survey years 1990, 1998 and 2007 and from the GMEP survey database covering the years 2013,’14.’15 and ’16.

The species lists from each quadrat were assigned to the units of the National Vegetation Classification using the MATCH algorithm as implemented in the MAVIS software package (Smart 2018). Since MAVIS only matches constancy tables consistent with the derivation of the NVC synoptic units, we converted % cover estimates for each species within each quadrat into constancy estimates using the translation in (Dring 2000). Having run all quadrats through MAVIS we selected the top 10 NVC unit fits. Quadrats were considered to represent unimproved neutral grassland by applying selection criteria as follows:

1. If the highest matching coefficient referred to any of the community or sub-community units included in MG4, MG5 or MG8 (Rodwell 1992).
2. If any of the top 5 matching coefficients included MG4, M5 or MG8 and equalled or exceeded the mean of the coefficients in step 1. Thus the mean of the coefficients for those quadrats where each of the units was the highest fit was used as a threshold for selecting a further set of plots in which the relevant NVC units featured in the top 5 matches but also reached at least the average coefficient in the first sample. This second step was done to widen the net but also ensure a good fit to the relevant units.

5.2.2 Results

A total of 51 quadrats were selected (Table 5.2.1). To allow assessment by expert users, data on species presence within quadrats are presented in Annex 6. For each of the three NVC units, tables in Annex 6 are ordered so that diagnostic species with high NVC constancy are at the top. Positive and negative species lists for semi-natural (unimproved) neutral grassland are presented in Annex 5.

Of the 51 quadrats, 34 were sampled during GMEP and 17 in the preceding Countryside Surveys. Hence overall these grassland communities are rare in the Welsh countryside. For example in GMEP there was a 1 in 4 chance of a random quadrat landing in Improved Grassland, 1 in 5 of landing in neutral grassland but only a 1 in 125 chance of sampling unimproved neutral grassland referable to MG4,5 or 8. This is based on a stratified random sample of 1km squares within which five stratified random plots were located in each survey year.

Differences in the count of positive and negative indicator species between survey years reflect differences in the distributions of quadrat types and the different sampling strategies associated with each type (Figs 5.2.1 and 5.2.2). In most survey years, especially Countryside Survey, unimproved neutral grasslands tend to have been sampled by Targeted plots. These were designed to represent species-rich patches of semi-natural habitat not sampled by the random plots. Therefore their elevated counts of both negative and positive indicators is bound to partly reflect this targeting strategy. The Unenclosed and Random plots provide an unbiased assessment suggested by the greater similarity in counts of indicator species across years. However, this potentially useful comparison is hampered by low counts of these quadrat types.

Table 5.2.1. *Numbers of quadrats assigned to each of the three NVC units representing unimproved neutral grassland in Wales.*

Survey year	MG4	MG5	MG8
1990	1	1	0
1998	3	4	2
2007	3	2	1
2013	2	3	4
2014	3	5	5
2015	0	7	0
2016	1	2	2
Total	**13**	**24**	**14**

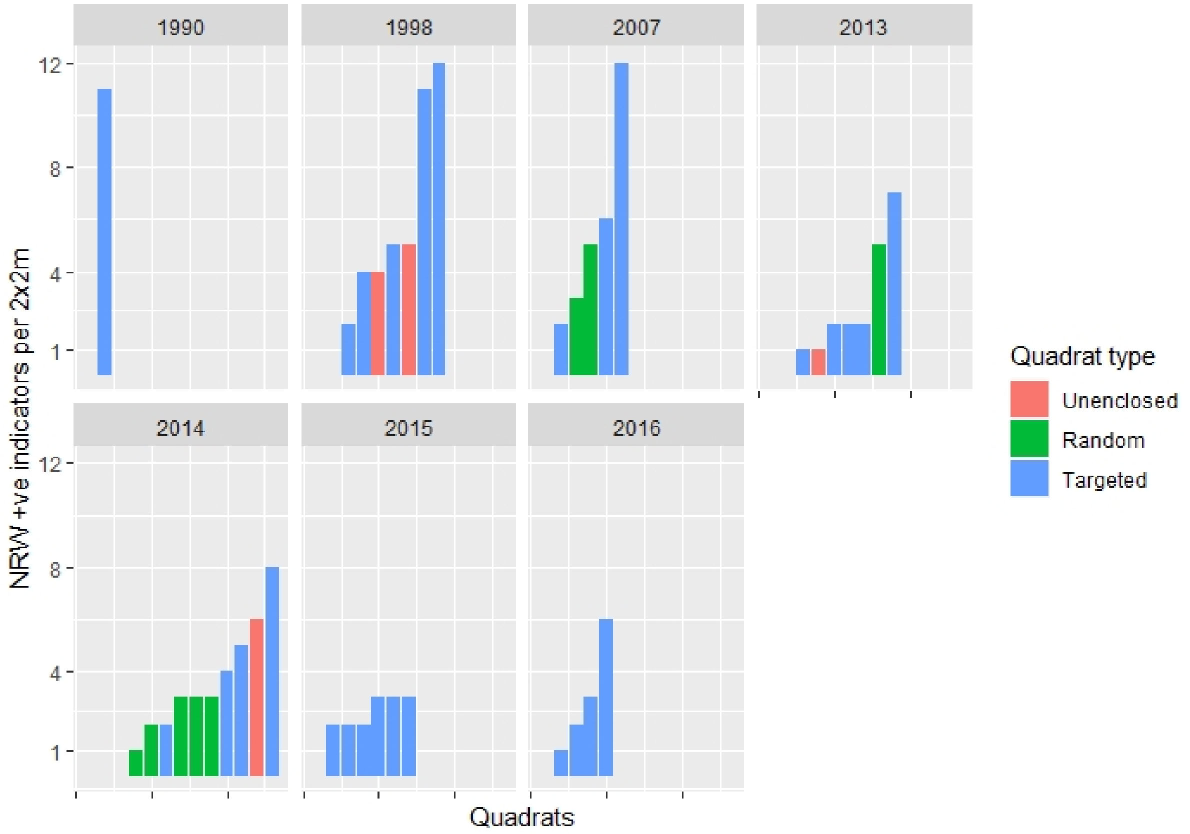


Figure 5.2.1: *Counts of <u>positive</u> (good condition) indicator species for each quadrat referable to MG4, 5 or 8 in Wales. Each bar is a 2x2m quadrat. Colour coding indicates the quadrat type. Unenclosed quadrats were randomly located within a constrained list of semi-natural habitats most often found in upland, unenclosed situations. Random quadrats were positioned at random in each 1km square and only constrained to avoid linear features. Targeted quadrats were specifically located in either species-rich patches of semi-natural habitat not sampled by the random quadrats or in 2007 and in GMEP 2016 in priority habitats.*

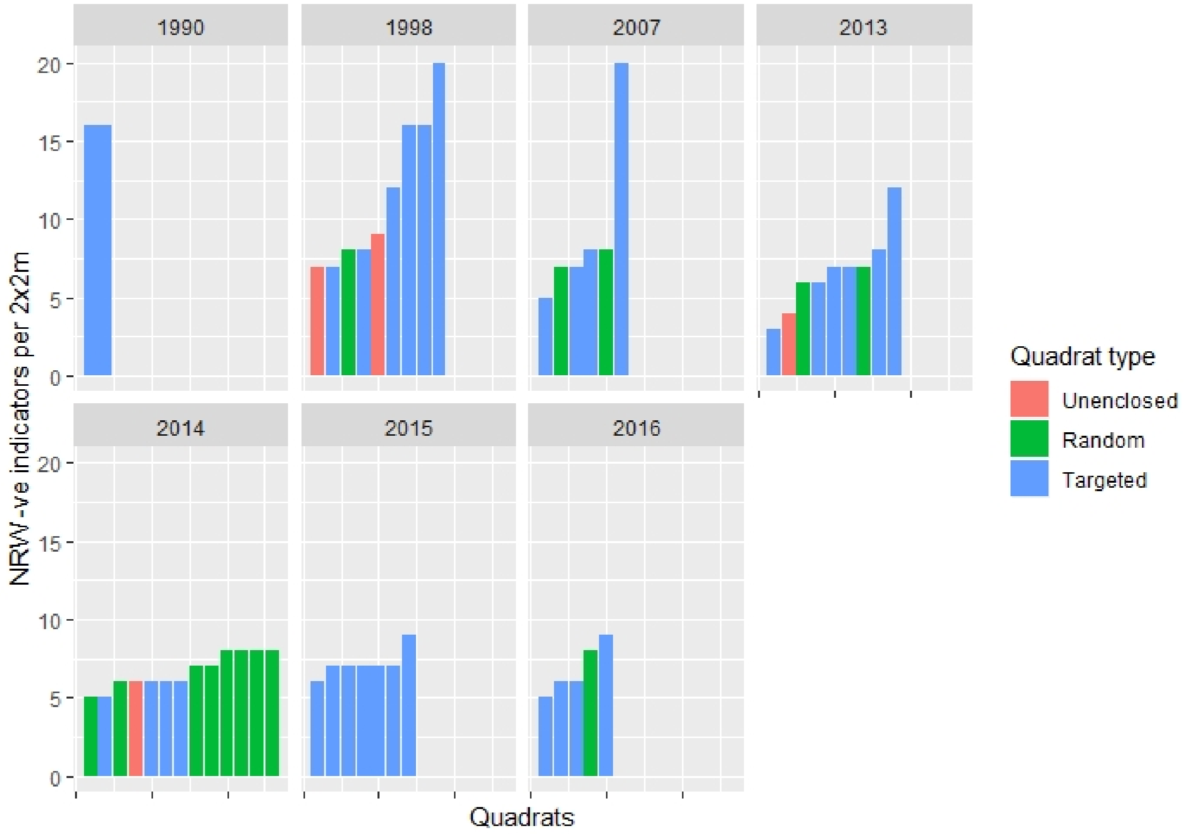


Figure 5.2.2: *Counts of <u>negative</u> (good condition) indicator species for each quadrat referable to MG4, 5 or 8 in Wales. Each bar is a 2x2m quadrat. Colour coding indicates the quadrat type.*

5.2.3 Discussion

The small numbers of CS and GMEP plots that sampled unimproved neutral grassland in Wales indicates that it would not be possible to conduct fruitful statistical analysis of change in condition over time. It would be possible to analyse all such quadrats recorded in Countryside Survey across Great Britain and introduce a country covariate to test whether there was a detectable signal of difference in trend or overall condition between countries.

Sample size would change for this analysis since all quadrats assigned to unimproved neutral grassland in any one year (Table 5.2.1) could be matched with their temporal repeat sampled in a different survey year even if not in the focal habitat. Such an analysis would give the fullest picture of change because it would be sensitive to changes in species composition that moved vegetation into or out of the focal community types. However, this analysis would still be likely to lack power because of low sample sizes.

Whilst the counts of indicator species are likely to reflect differences in sampling strategy, the values calculated for the random and unenclosed quadrats derive from unbiased sampling. Despite being a small sample additional insight into the condition of these quadrats could be gained from comparing species composition and values against reference data for the same units based on wider NVC survey data for Wales.

6 Analyses for Mountain, Moor & Heath

6.1 Trends: Vegetation condition and species richness

The Glastir Monitoring and Evaluation Programme (GMEP) final report presented an analysis of trends in condition of woodland, improved land and "habitat" land (all non-woodland, non-improved land; Emmett and the GMEP team 2017). The report found a recent increase in the condition of habitat land, as measured by (1) total species richness of vascular plants and (2) the richness of species that are positive indicators of any Common Standards Monitoring habitat (https://jncc.gov.uk/our-work/common-standards-monitoring-guidance/). The GMEP final report also indicated an upward trend in the richness of positive indicator species on blanket bog priority habitat since 1990.

The GMEP "habitat" category included mountain, moor and heath (MMH) habitats alongside many other habitat types. Further work was undertaken to produce a trend specific to MMH in the ERAMMP Report 20 (Maskell et al. 2019a). The resulting trend confirmed a recent increase in the condition and species richness of MMH, indicating recovery to levels seen pre-2007. This trend was constructed including dwarf shrub heath; bog; bracken; fen, marsh & swamp, montane, and inland rock broad habitat types.

Further work was required to separately assess trends in condition of heath and bog habitats based on a tailored list of positive indicator species, rather than a generic list relevant to all semi-natural habitats. Furthermore, some negative indicator species needed to be removed from the analysis for these habitats.

Here we improve reporting of MMH condition in three ways:

1) We report separately on bog and heath habitats. Previous analysis in the GMEP final report focussed on blanket bog priority habitat, but here we report on bog habitats more widely.
2) For each reporting category, we derive condition as the species richness of positive indicators specifically relevant to that category. Species lists were reviewed and amended by SoNaRR technical leads at NRW to ensure that they were fit for purpose.
3) For each reporting category, in the analysis of overall species richness we remove a specific list of species which are negative indicators for that category. Species lists were reviewed and amended by SoNaRR technical leads at NRW to ensure that they were fit for purpose.

6.1.1 Methods

Vegetation surveys

In each 1km square, plant species presence and cover was recorded in different sizes and types of vegetation plot (Emmett and the GMEP team 2017, Wood et al. 2017). Random points marking the position of five random or 'nested' plots (X plots) in each square were determined prior to the field survey. The locations, type and numbers of other kinds of plot were determined based on a rule-set, using the 'nested' plots as a starting point (or based on other mapping exercises). For more information on GMEP square selection and vegetation sampling methodology, see the GMEP reports and appendices https://gmep.wales/. Three particular plot types are relevant to this report:

1) Nested plots to provide a random sample of common vegetation types (X plots). Only the inner 2x2m area of these plots is used here for consistency across plot types and survey years.
2) Targeted 2x2m plots to sample Priority Habitats and locations eligible for Glastir (Y plots).
3) Unenclosed 2x2m plots to sample unenclosed Broad Habitats (U plots).

Data analysis

For each of three reporting categories (heath and bog), we extracted the relevant vegetation plots from Countryside Survey (CS) and GMEP surveys. We included random plots (“X plots”) as well as stratified random plots from unenclosed habitats (“U plots”) and plots targeted to priority habitats (“Y plots”) in the analysis (Wood et al. 2017). We calculated the richness of positive indicator species, and overall vascular plant species richness excluding negative indicators, using category-specific species lists reviewed by NRW technical leads. Positive and negative species lists for heath and bog are presented in Annex 5.

We analysed trends in species richness using linear mixed-effects models (LMMs) in the *R* package *nlme* (Pinheiro et al. 2019, R Core Team 2019). Species richness was log-transformed to ensure model residuals resembled a Gaussian distribution. We used a fixed effect for survey year with a correlation structure to account for repeated measures in CS and GMEP surveys.

6.1.2 Results

Heath: Condition

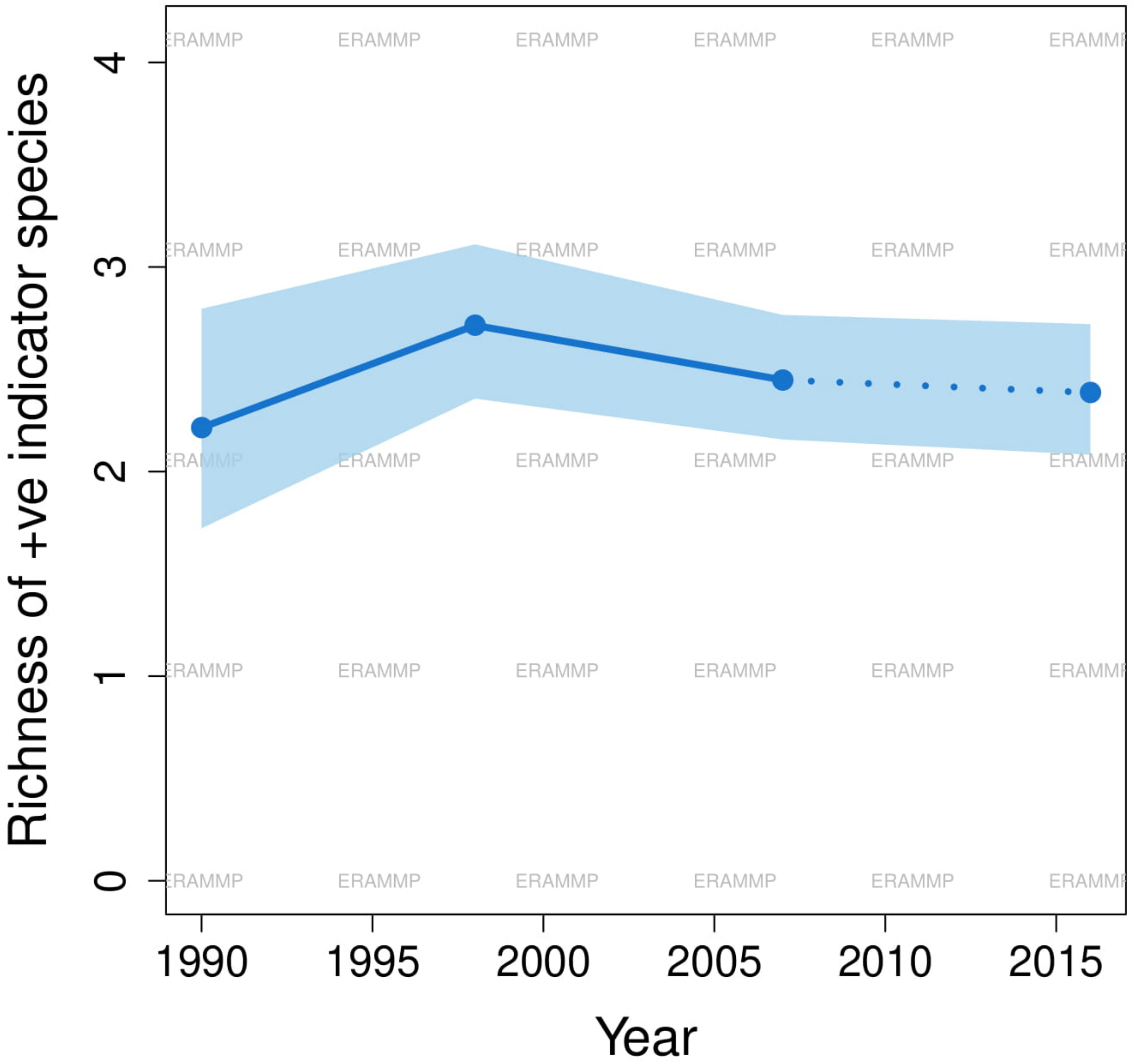


Figure 6.1.1. *Richness of positive indicator species in vegetation plots on heath from 1990-2016. Blue dots represent estimates from a linear mixed-effect model, including year as a fixed effect. The light blue area above and below each estimate represents 95% confidence intervals. Data from 1990-2007 are from Countryside Survey; data from 2016 are from the Glastir Monitoring and Evaluation Programme.*

Table 6.1.1. *Estimates of richness of positive indicator species in vegetation on heath from 1990-2016.* P-*values are shown for pairwise comparisons between GMEP 2016 and other survey years. The number of plots included in the analysis for heath is also shown. "↔" represents non-significance in a trend, indicating stability and/or low sample size.*

Year	Species richness estimate	*P*-value vs. 2016	Number of plots	Long-term trend	Short-term trend
1990	2.21	0.58	18	↔	↔
1998	2.71	0.19	57		
2007	2.45	0.78	80		
2016	2.39	NA	73		

Heath: Species richness

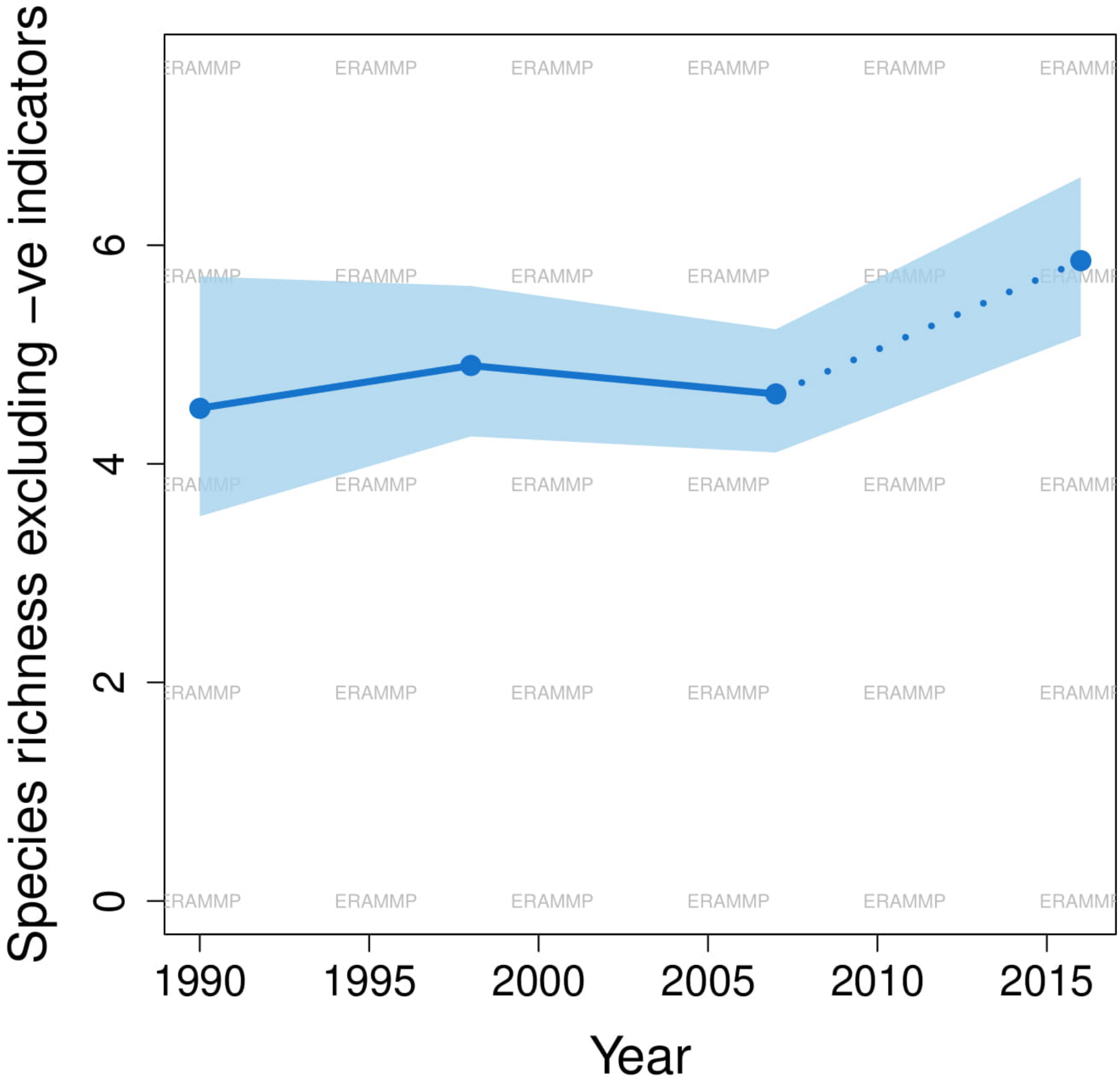


Figure 6.1.2. *Species richness in vegetation plots on heath from 1990-2016 (excluding negative indicator species). Blue dots represent estimates from a linear mixed-effect model, including year as a fixed effect. The light blue area above and below each estimate represents 95% confidence intervals. Data from 1990-2007 are from Countryside Survey; data from 2016 are from the Glastir Monitoring and Evaluation Programme.*

Table 6.1.2. *Estimates of Species richness in vegetation plots on heath from 1990-2016 (excluding non-native species).* P-*values are shown for pairwise comparisons between GMEP 2016 and other survey years. The number of plots included in the analysis for heath is also shown. "↔" represents non-significance in a trend, indicating stability and/or low sample size.*

Year	Species richness estimate	*P*-value vs. 2016	Number of plots	Long-term trend	Short-term trend
1990	4.51	0.06	18	↔	↑
1998	4.90	0.06	57		
2007	4.64	**0.01**	80		
2016	5.86	NA	73		

Bog: Condition

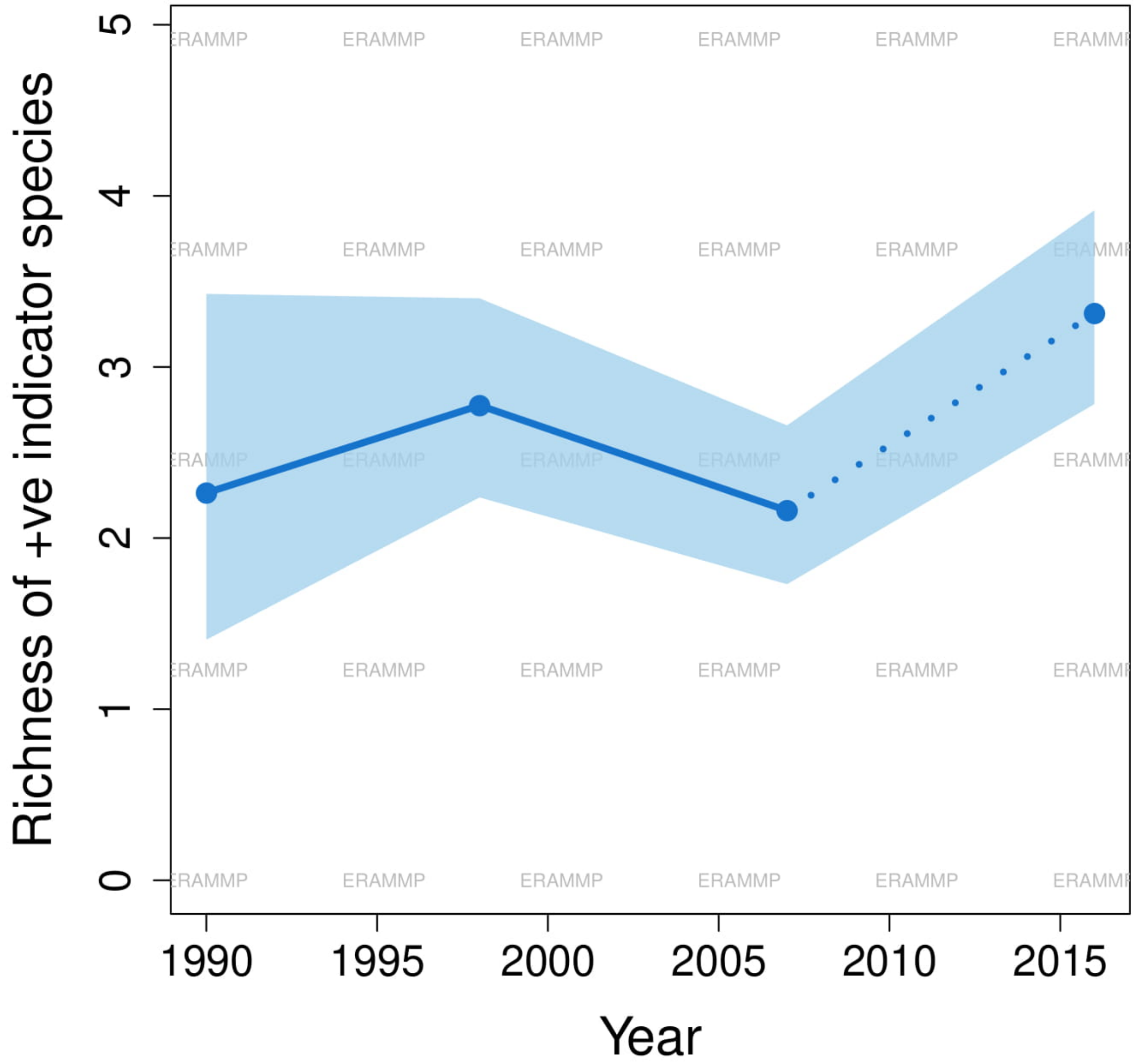


Figure 6.1.3. *Richness of positive indicator species in vegetation plots on bog from 1990-2016. Blue dots represent estimates from a linear mixed-effect model, including year as a fixed effect. The light blue area above and below each estimate represents 95% confidence intervals. Data from 1990-2007 are from Countryside Survey; data from 2016 are from the Glastir Monitoring and Evaluation Programme.*

Table 6.1.3. *Estimates of richness of positive indicator species in vegetation plots on bog from 1990-2016.* P*-values are shown for pairwise comparisons between GMEP 2016 and other survey years. The number of plots included in the analysis for bog is also shown. "↔" represents non-significance in a trend, indicating stability and/or low sample size.*

Year	Species richness estimate	*P*-value vs. 2016	Number of plots	Long-term trend	Short-term trend
1990	2.26	0.11	9	↔	↑
1998	2.77	0.21	45		
2007	2.16	**<0.01**	52		
2016	3.31	NA	73		

Bog: Species richness

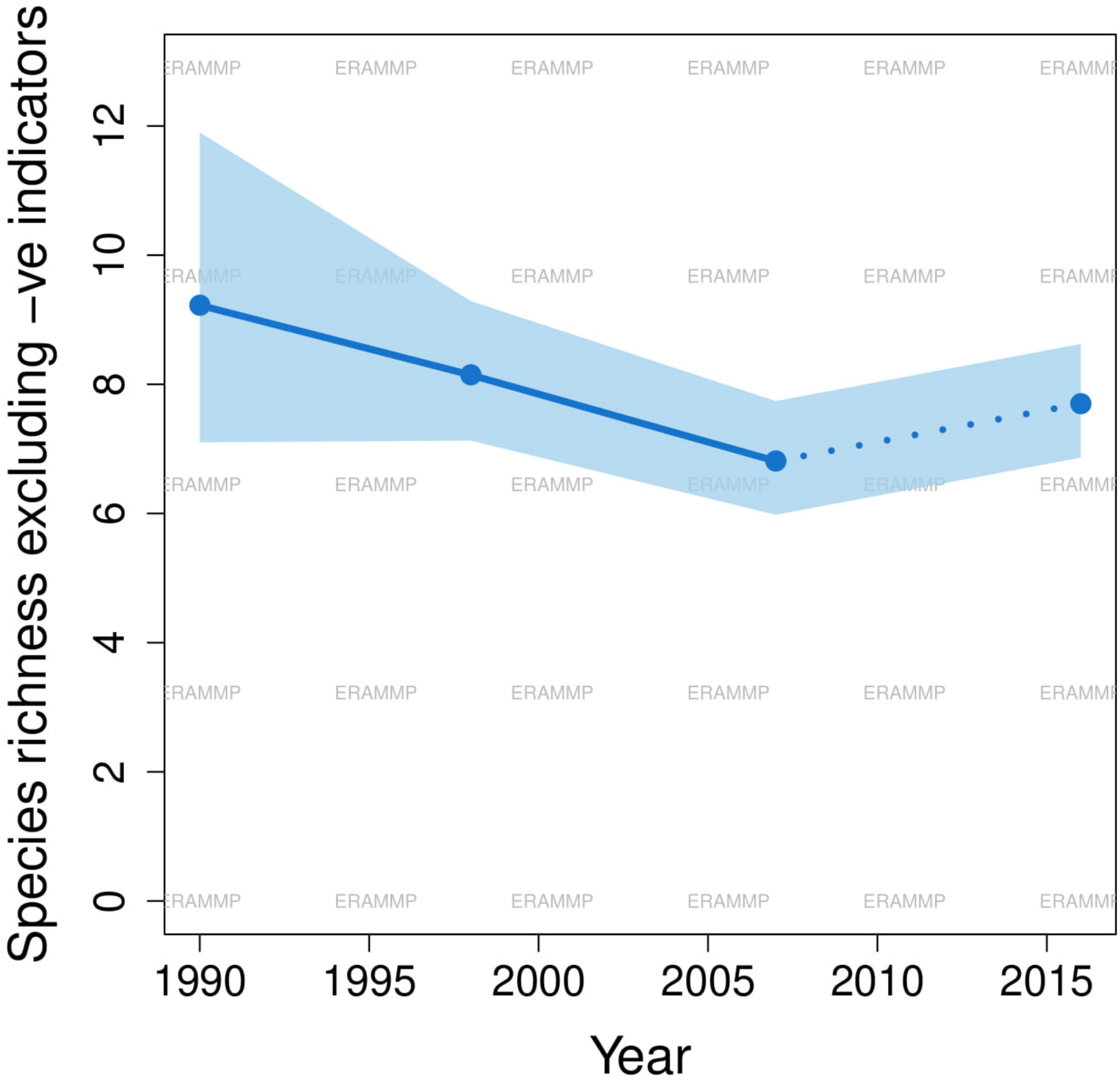


Figure 6.1.4. *Species richness in vegetation plots on bog from 1990-2016 (excluding negative indicator species). Blue dots represent estimates from a linear mixed-effect model, including year as a fixed effect. The light blue area above and below each estimate represents 95% confidence intervals. Data from 1990-2007 are from Countryside Survey; data from 2016 are from the Glastir Monitoring and Evaluation Programme.*

Table 6.1.4. *Estimates of Species richness in vegetation plots on bog from 1990-2016 (excluding non-native species).* P-*values are shown for pairwise comparisons between GMEP 2016 and other survey years. The number of plots included in the analysis for bog is also shown. "↔" represents non-significance in a trend, indicating stability and/or low sample size.*

Year	Species richness estimate	*P*-value vs. 2016	Number of plots	Long-term trend	Short-term trend
1990	9.22	0.22	9	↔	↔
1998	8.14	0.53	45		
2007	6.81	0.17	52		
2016	7.70	NA	73		

6.1.3 Discussion

These results depict trends in the condition of MMH in Wales at a higher definition than has been previously reported.

Positive outcomes / improvements

New results for heath suggest increases in species richness of vascular plants, excluding negative indicators, since 2007 (Fig. 6.1.2, Table 6.1.2), while new results for bog suggest increases in species richness of positive indicators over the same period (Fig. 6.1.3, Table 6.1.3). This work provides up-to-date condition trends for heath and bog based on species lists approved by NRW. Future field survey visits under ERAMMP will add another time-point to trends, providing further confirmation of the trajectory of MMH condition in Wales.

7 Analyses for Woodland

7.1 Trends: Vegetation condition and species richness

The Glastir Monitoring and Evaluation Programme (GMEP) final report presented an analysis of trends in habitat condition of woodland, improved land and "habitat" land (all non-woodland, non-improved land; Emmett and the GMEP team 2017). The report indicated that trends in broadleaved woodland across Wales were non-significant in terms of (1) total species richness of vascular plants and (2) the richness of ancient woodland indicators. (https://jncc.gov.uk/our-work/common-standards-monitoring-guidance/).

The ERAMMP year 20 report (Maskell et al. 2019a) presented an improved analysis of plant biodiversity in broadleaved woodland, suggesting short-term increases in species richness of both vascular plants and ancient woodland indicators since 2007. However, further work was required to present trends for coniferous woodland in Wales. Furthermore, removal of non-native species from the vascular plant species richness analysis was considered desirable.

Here we improve reporting of woodland condition in two ways:

1) We report on separate woodland categories – specifically broadleaved mixed & yew woodland and coniferous woodland broad habitats.

2) For each woodland category, in the analysis of vascular plant species richness we remove non-native species, as requested by NRW SoNaRR technical leads.

7.1.1 Methods

Vegetation surveys

In each 1km square, plant species presence and cover was recorded in different sizes and types of vegetation plot (Emmett and the GMEP team 2017, Wood et al. 2017). Random points marking the position of five random or 'nested' plots (X plots) in each square were determined prior to the field survey. The locations, type and numbers of other kinds of plot were determined based on a rule-set, using the 'nested' plots as a starting point (or based on other mapping exercises). For more information on GMEP square selection and vegetation sampling methodology, see the GMEP reports and appendices https://gmep.wales/. Three particular plot types are relevant to this report:

1) Nested plots to provide a random sample of common vegetation types (X plots). Only the inner 2x2m area of these plots is used here for consistency across plot types and survey years.
2) Targeted 2x2m plots to sample Priority Habitats and locations eligible for Glastir (Y plots).
3) Unenclosed 2x2m plots to sample unenclosed Broad Habitats (U plots).

Data analysis

For each of two reporting categories (broadleaved woodland and coniferous woodland), we extracted the relevant vegetation plots from Countryside Survey (CS) and GMEP surveys. We included random plots (“X plots”) as well as plots targeted to priority habitats (“Y plots”) in the analysis (Wood et al. 2017). We calculated the richness of positive indicators i.e. ancient woodland indicator species (Annex 5), and overall vascular plant species richness excluding non-native species. Species were considered to be non-native if they were classed as alien: casual (including many crop species) or alien: neophyte (introduced after 1500; Preston et al. 2002). We analysed trends in species richness using linear mixed-effects models (LMMs) in the *R* package *nlme* (Pinheiro et al. 2019, R Core Team 2019). Species richness was log-transformed to ensure model residuals resembled a Gaussian distribution. We used a fixed effect for survey year with a correlation structure to account for repeated measures in CS and GMEP surveys.

7.1.2 Results

Broadleaved woodland: Condition

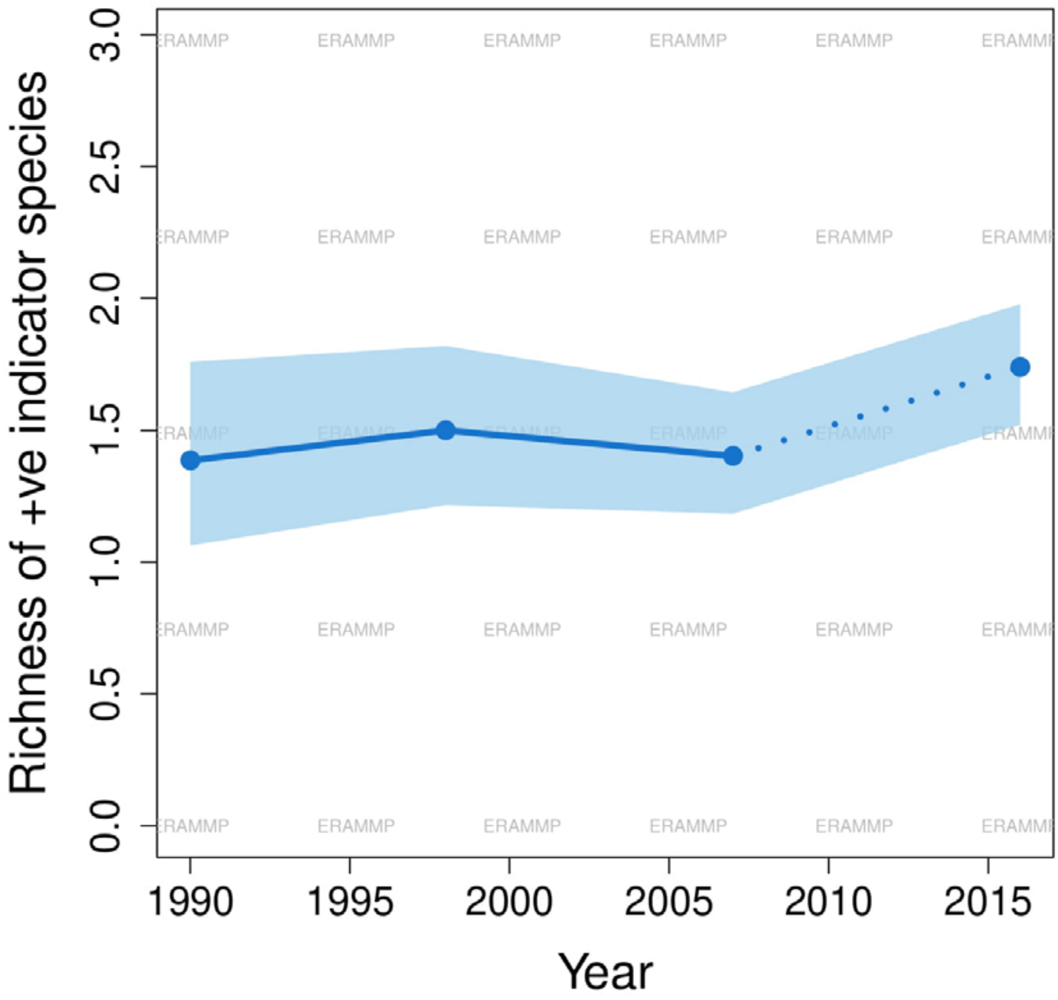


Figure 7.1.1. *Richness of positive indicator species in vegetation plots in broadleaved woodland from 1990-2016. Blue dots represent estimates from a linear mixed-effect model, including year as a fixed effect. The light blue area above and below each estimate represents 95% confidence intervals. Data from 1990-2007 are from Countryside Survey; data from 2016 are from the Glastir Monitoring and Evaluation Programme.*

Table 7.1.1. *Estimates of richness of positive indicator species in vegetation plots in broadleaved woodland from 1990-2016.* P*-values are shown for pairwise comparisons between GMEP 2016 and other survey years. The number of plots included in the analysis for broadleaved woodland is also shown. "↔" represents non-significance in a trend, indicating stability and/or low sample size.*

Year	Species richness estimate	*P*-value vs. 2016	Number of plots	Long-term trend	Short-term trend
1990	1.39	0.10	50	↔	↑
1998	1.50	0.21	80		
2007	1.40	**0.04**	158		
2016	1.74	NA	223		

Broadleaved woodland: Species richness

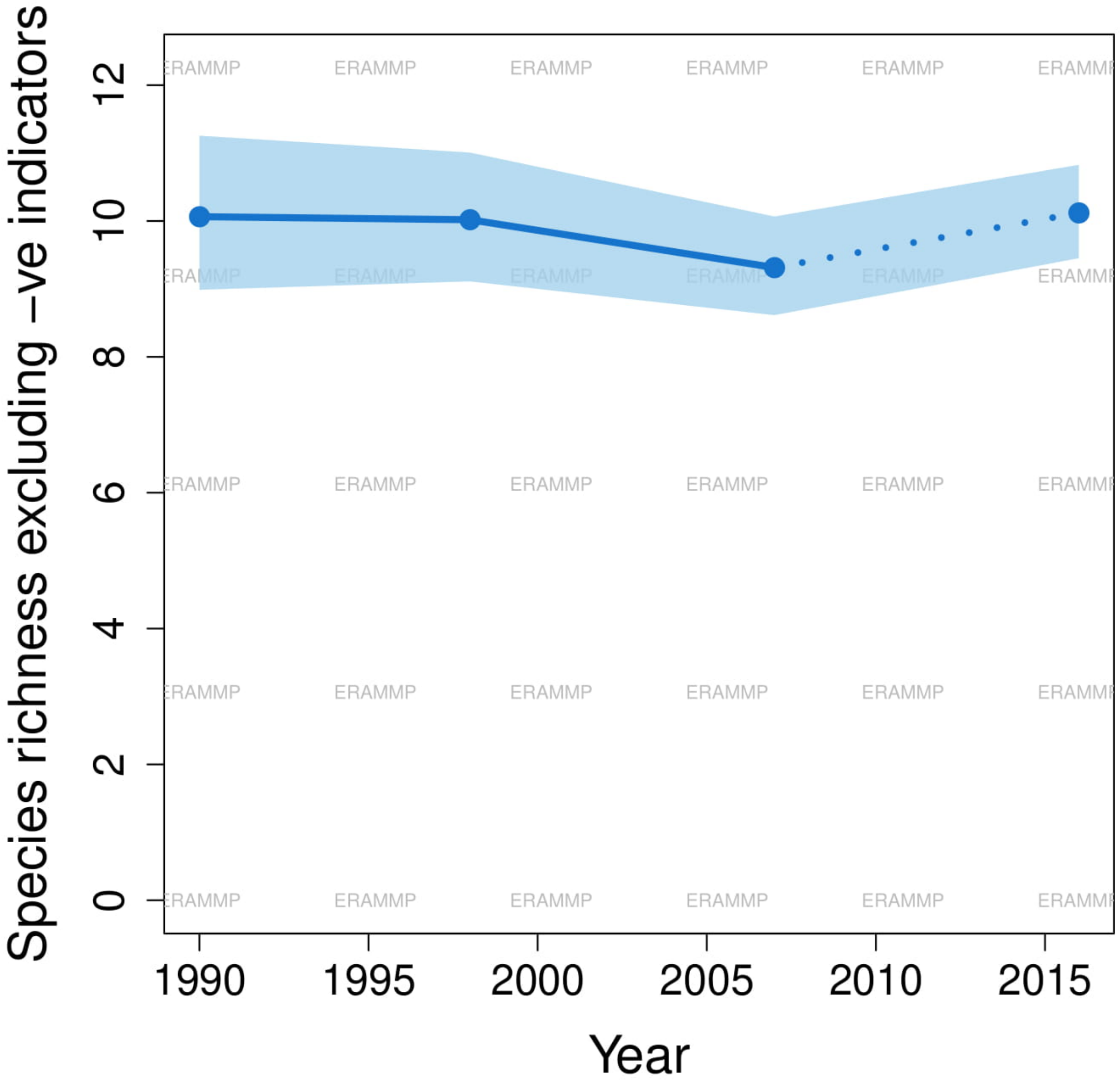


Figure 7.1.2. *Species richness in vegetation plots in deciduous woodland from 1990-2016 (excluding non-native species). Blue dots represent estimates from a linear mixed-effect model, including year as a fixed effect. The light blue area above and below each estimate represents 95% confidence intervals. Data from 1990-2007 are from Countryside Survey; data from 2016 are from the Glastir Monitoring and Evaluation Programme.*

Table 7.1.2. *Estimates of Species richness in vegetation plots in deciduous woodland from 1990-2016 (excluding non-native species).* P*-values are shown for pairwise comparisons between GMEP 2016 and other survey years. The number of plots included in the analysis for deciduous woodland is also shown. "↔" represents non-significance in a trend, indicating stability and/or low sample size.*

Year	Species richness estimate	*P*-value vs. 2016	Number of plots	Long-term trend	Short-term trend
1990	10.06	0.93	50	↔	↔
1998	10.02	0.86	80		
2007	9.31	0.10	158		
2016	10.12	NA	223		

Coniferous woodland: Condition

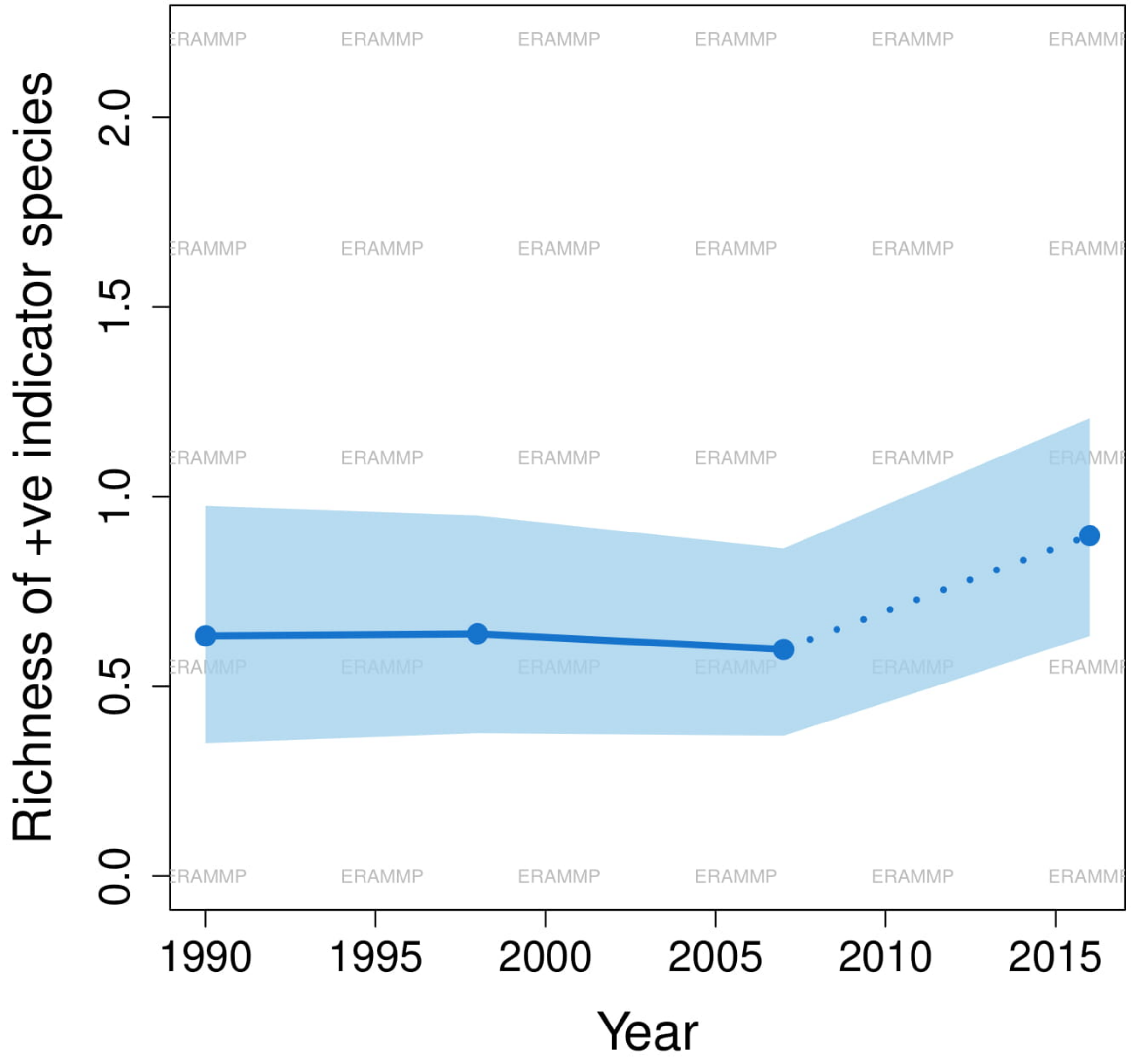


Figure 7.1.3. *Richness of positive indicator species in vegetation plots in coniferous woodland from 1990-2016. Blue dots represent estimates from a linear mixed-effect model, including year as a fixed effect. The light blue area above and below each estimate represents 95% confidence intervals. Data from 1990-2007 are from Countryside Survey; data from 2016 are from the Glastir Monitoring and Evaluation Programme.*

Table 7.1.3. *Estimates of richness of positive indicator species in vegetation plots in coniferous woodland from 1990-2016.* P*-values are shown for pairwise comparisons between GMEP 2016 and other survey years. The number of plots included in the analysis for coniferous woodland is also shown. "↔" represents non-significance in a trend, indicating stability and/or low sample size.*

Year	Species richness estimate	*P*-value vs. 2016	Number of plots	Long-term trend	Short-term trend
1990	0.63	0.21	28	↔	↔
1998	0.64	0.20	35		
2007	0.60	0.11	47		
2016	0.90	NA	52		

Coniferous woodland: Species richness

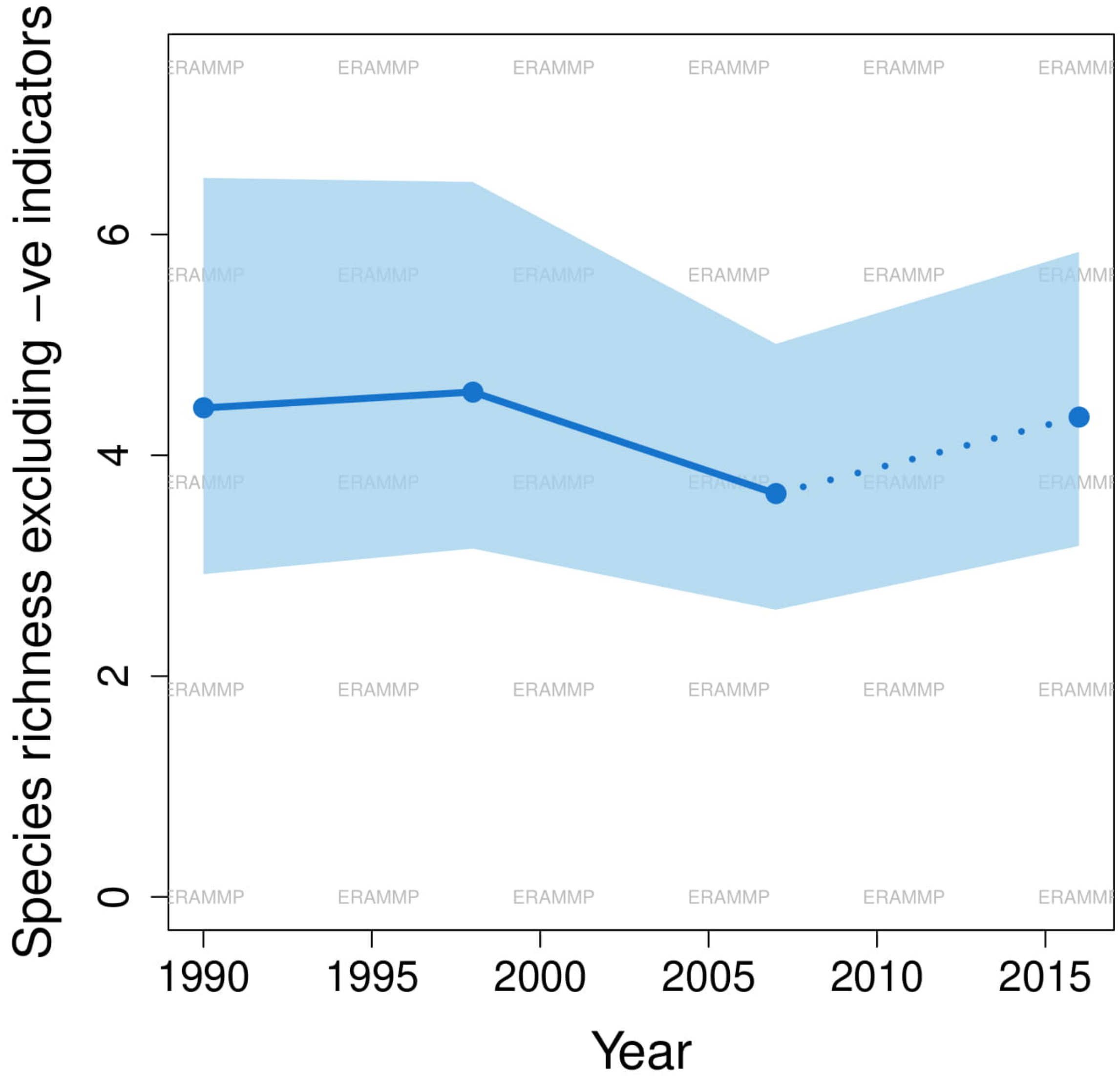


Figure 7.1.4. *Species richness in vegetation plots in coniferous woodland from 1990-2016 (excluding non-native species). Blue dots represent estimates from a linear mixed-effect model, including year as a fixed effect. The light blue area above and below each estimate represents 95% confidence intervals. Data from 1990-2007 are from Countryside Survey; data from 2016 are from the Glastir Monitoring and Evaluation Programme.*

Table 7.1.4. *Estimates of Species richness in vegetation plots in coniferous woodland from 1990-2016 (excluding non-native species).* P-*values are shown for pairwise comparisons between GMEP 2016 and other survey years. The number of plots included in the analysis for coniferous woodland is also shown. "↔" represents non-significance in a trend, indicating stability and/or low sample size.*

Year	Species richness estimate	*P*-value vs. 2016	Number of plots	Long-term trend	Short-term trend
1990	4.43	0.94	28	↔	↔
1998	4.57	0.83	35		
2007	3.65	0.43	47		
2016	4.35	NA	52		

7.1.3 Discussion

These results depict trends in the condition of woodland in Wales at a higher definition than has been previously reported.

Positive outcomes / improving

As in the ERAMMP Report-20: *Re-analysis of data for SoNaRR* (Maskell et al. 2019a), there was a significant increase in the richness of positive indicator species in deciduous woodland between 2007 and 2016 (Fig. 7.1.1, Table 7.1.1). However, the trend in vascular plant species richness minus negative indicators from 2007-2016 is presently not significant (P = 0.10, Fig. 2, Table 2). The significance of this trend has changed since the previous analysis (Maskell et al. 2019a). This could be because the previous analysis included non-native species, while the present analysis does not.

Areas for concern

New results for coniferous woodland suggest no significant positive or negative trends in species richness since 1990 – either for ancient woodland indicators or for vascular plants in general. Furthermore, these results reveal that the number of native plant species recorded per 2x2m quadrat in coniferous woodland is usually less than half the average number for broadleaved woodland (Tables 7.1.2 & 7.1.4). The difference is similar for species richness of ancient woodland indicators (Tables 7.1.1 & 7.1.3).

Future work could use a refined list of ancient woodland indicators, specifically relevant to woodland condition in Wales. Furthermore, future field survey visits under ERAMMP will add another time-point to trends, providing further confirmation of the trajectory of woodland condition in Wales.

7.2 State: Non-native and faunal indicator vegetation

We present further analysis of data from 2x2m vegetation quadrats recorded during GMEP, with data shown separately for deciduous and coniferous woodland where possible. There are two relevant types of vegetation plot included in this analysis: X plots (hereafter "X1") which are positioned randomly in survey squares, and Y plots which are placed randomly by surveyors in suitable patches of vegetation (i.e. they are biased towards small patches of semi-natural habitat which are suspected of being priority habitat; Wood et al. 2017). For coniferous woodlands there were very few Y plots (n = 4), so the two plot types are grouped together (n = 52). For broadleaved woodland data are presented for X1 (n = 46) and Y (n = 183) plots separately. In this way we present the state of broadleaved woodlands at large (X1) and broadleaved woodlands which are likely to be priority habitat (Y).

We present data on:

- Species richness of (1) native species, (2) food plants for butterfly larvae, and (3) nectar plants
- Presence of non-native understorey plant species, specifically highlighting *Rhododendron* where present
- Cover of a set of non-native invasive species – particularly *Impatiens glandulifera*, *Heracleum mantegazzanium*, and *Fallopia japonica*
- Cover of dormouse habitat indicator species: *Rubus fruticosus*, honeysuckle, hazel and oak

7.2.1 Methods

Data analysis

Poisson models were fitted as part of an analysis into the counts of native species per plot (where native comprises the following groups: Archaeophytes (alien introduced prior to 1500), native non-endemics, native endemics, and spontaneous hybrids between two native plants), counts of food plants for butterfly larvae per plot (as listed in Smart et al. 2000), and counts of nectar plants per plot (based on a list provided by Richard Pywell and Claire Carvell and used in Carvell et al. 2006), using different plot types as predictors. The number of plots where non-native understorey species were present were compared with those where they were absent. Plots with *Rhododendron* present are also highlighted. Similarly, the proportion of all plots containing a set of invasive species (including *Impatiens glandulifera*, *Heracleum mantegazzanium*, and *Fallopia japonica*) was calculated for each of the two broadleaved plot types and the coniferous plots combined. Distributions of the dormouse habitat indicator, *Rubus fruticosus* cover were non-parametric and compared using a Kruskal-Wallis rank sum test. In broadleaved woodland plots, the percentage covers of honeysuckle, hazel and oak (dormouse habitat condition indicators) were calculated. Here, the mean, median, 75th, 90th and 95th percentiles are presented for the X1 and Y plots. All analyses were completed using *R* (R Core Team 2019).

7.2.2 Results

- Counts of native species, food plants for butterfly larvae, and nectar plants were highest on average for the broadleaved Y plots, followed by the X1 plots and the combined coniferous plot datasets (Figure 7.2.1).

- The number of plots where non-native understorey plant species were absent outnumbered plots where they were present for both the broadleaved X1 and Y plots and all coniferous plots (Figure 7.2.2). A small percentage of broadleaved Y plots and coniferous plots had *Rhododendron* present (Table 7.2.1).
- Broadleaved X1 plots had the highest proportion of the analysed invasive species at 2.17%, followed by the coniferous plots at 1.92% and the broadleaved Y plots at 1.64% (Table 7.2.2).
- Distributions of *Rubus fruticosus* were positively skewed for all analysed plot groups, with most plots containing a fraction of 1% coverage, but a small number of plots with >50% coverage (Figure 7.2.3). Kruskal-Wallis rank sum testing indicated no statistically significant difference among the different plot types ($p > 0.05$ significance level).
- The vast majority of broadleaved plots contained no honeysuckle, hazel or oak cover (Figure 7.2.4). Oak was the most abundant of the 3 species, occurring in the top 25% of plots and rising to 90-100% coverage in the top 5% of plots. Hazel was the next most abundant, with over 50% coverage in the top 10% of Y plots and top 5% of X1 plots. Honeysuckle cover was greater in the top 10 and top 5% of X1 plots compared with the same percentiles of Y plots.

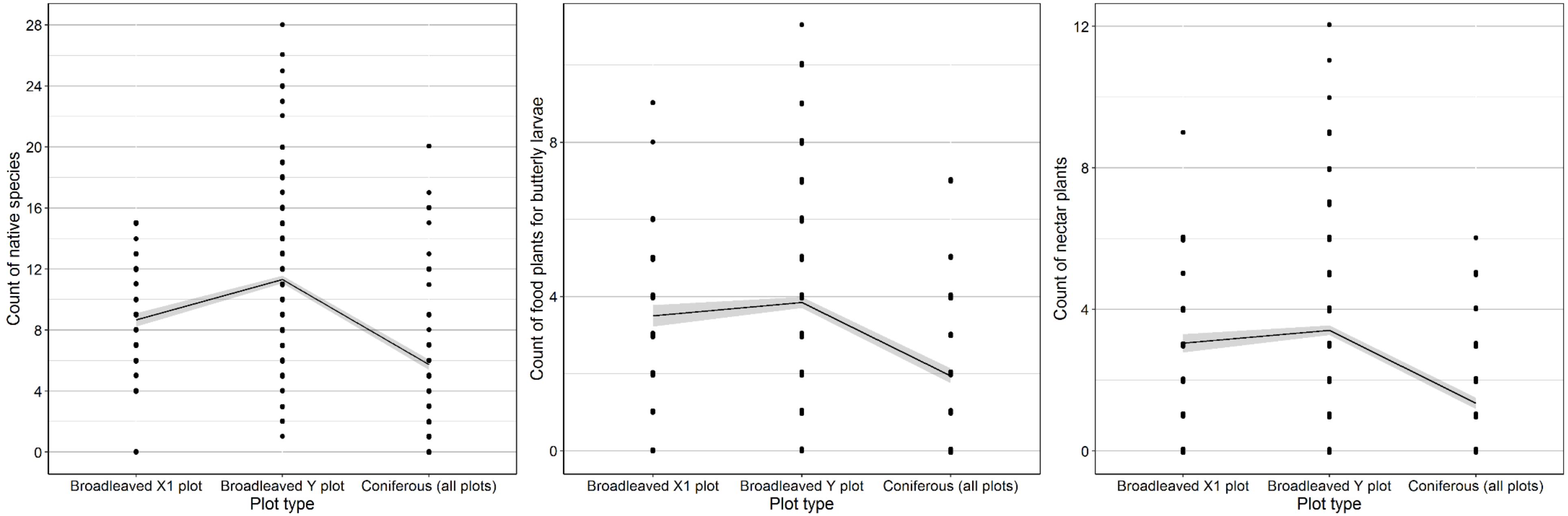


Figure 7.2.1 Counts of native species, food plants for butterfly larvae, and nectar plants for the broadleaved X1 and Y plots, and the coniferous plots (X1 and Y plots combined). Poisson distribution models (±1 standard error) are fitted to the three plant count datasets (see Annex 7 for details of model parameters).

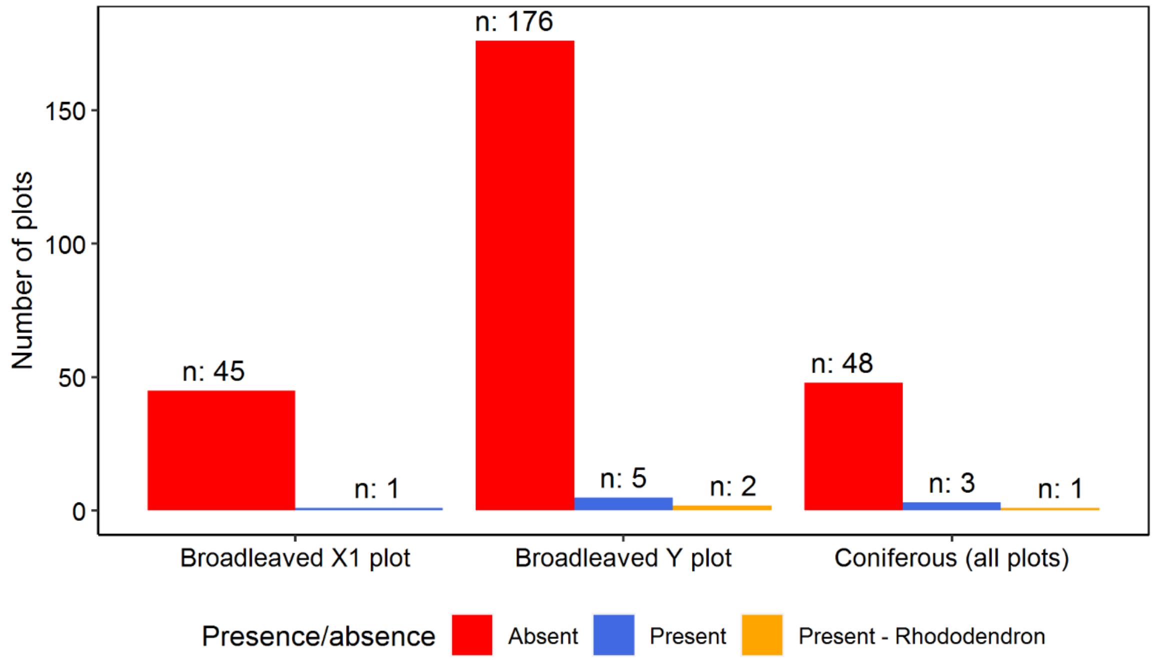


Figure 7.2.2 *Total number of plots where non-native understorey plant species are absent compared with where non-native species are present in 2016. Data are grouped into broadleaved X1 plots and Y plots, and coniferous plots combined. Presence of Rhododendron is also recorded. Note the total number of plots where any non-natives are present would be the sum of blue (present) and yellow (present - Rohododendron) bars.*

Table 7.2.1 *Percentage of total plots for each plot type in 2016 where non-native ground flora and* Rhododendron *are present. Plots where just* Rhododendron *are present are also shown.*

Plot type	Absent (%)	Present - any (%)	Present - *Rhododendron* only (%)
Broadleaved X1	97.83	2.17	0
Broadleaved Y	96.17	3.83	1.09
Coniferous (all)	92.31	7.69	1.92

Table 7.2.2 *Percentage of total invasive species cover in 2016 (including Impatiens glandulifera, Heracleum mantegazzanium, and Fallopia japonica) present in each plot type.*

Plot type	Total cover (%)
Broadleaved X1	2.17%
Broadleaved Y	1.64%
Coniferous (all)	1.92%

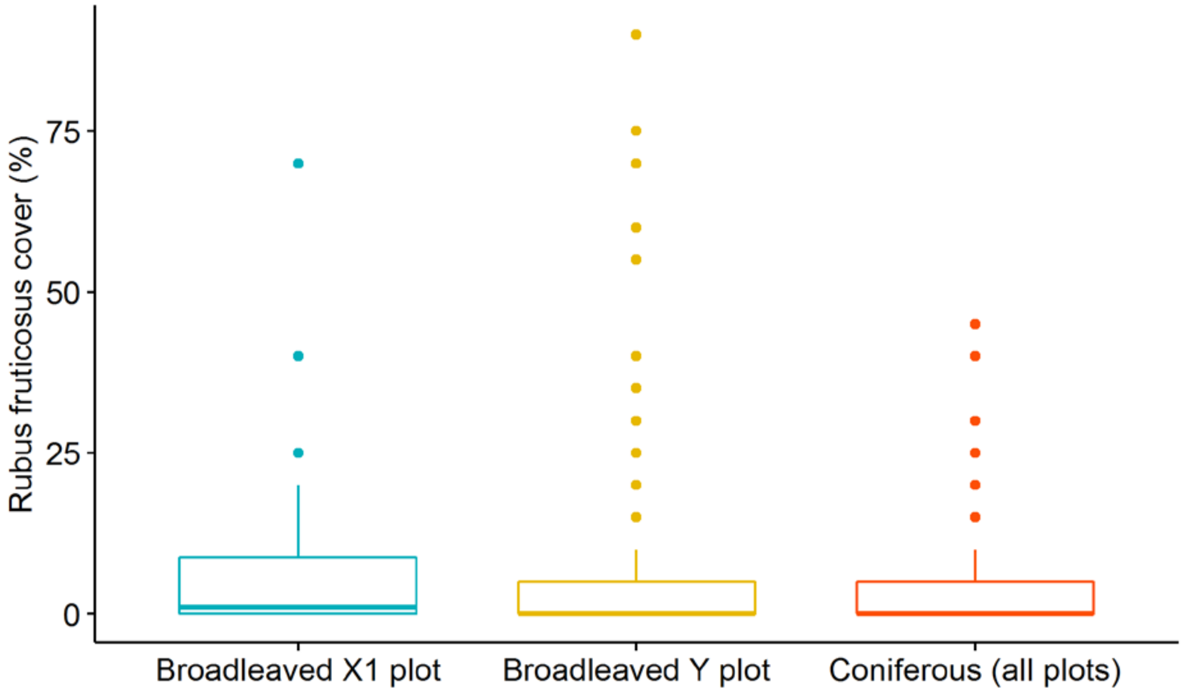


Figure 7.2.3 *Distributions of Rubus fruticosus cover for the 3 plot type groupings in 2016: Broadleaved (X1), Broadleaved (Y) and Coniferous (all). Boxes represent the interquartile range (IQR; from the 25th to 75th percentiles), and include the median (thick horizontal line). The maximum (upper whisker) is equal to the 75th percentile plus 1.5 times the IQR. Kruskal-Wallis rank sum testing indicated no statistically significant difference among the groups (p > 0.05).*

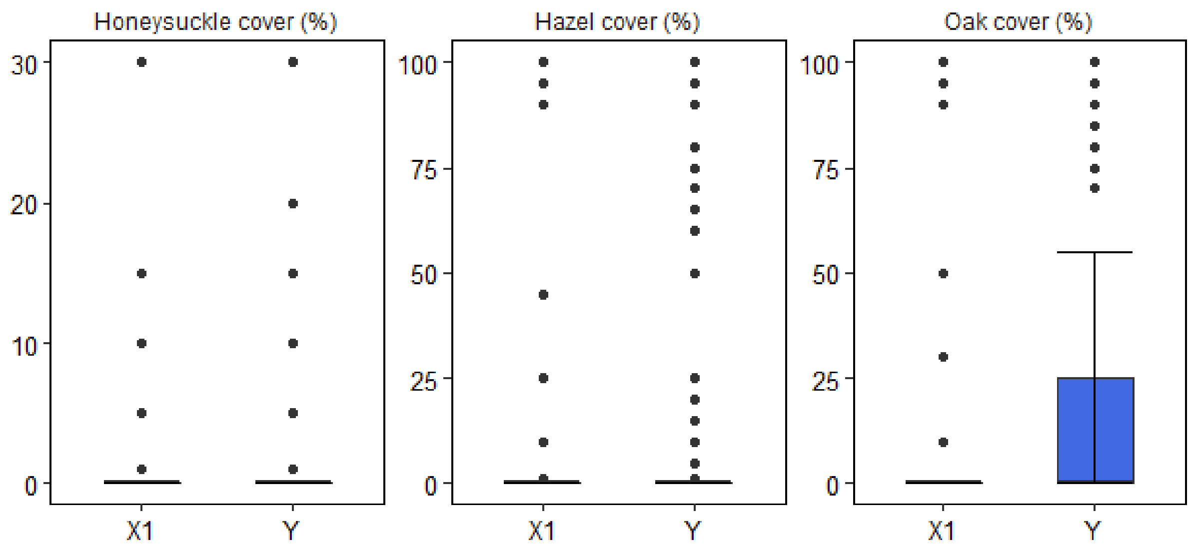


Figure 7.2.4 *Distributions of honeysuckle, hazel and oak cover (%) for the Broadleaved X1 and Y plots in 2016. Boxes represent the interquartile range, IQR (from the 25th to 75th percentiles) and include the median (thick horizontal line). The maximum (upper whisker) is equal to the 75th percentile plus 1.5 times the IQR.*

Table 7.2.3 *Averages and percentiles of honeysuckle, hazel and oak cover in broadleaved woodland habitats.*

Broadleaved woodland cover (%)	Mean	Median	75th percentile	90th percentile	95th percentile
All broadleaved woodland plots					
Honeysuckle	0.8	0	0	0.2	3.4
Hazel	11.3	0	0	66	90
Oak	20.4	0	20	95	100
X1 plots					
Honeysuckle	1.3	0	0	1	8.8
Hazel	10.1	0	0	35	93.8
Oak	13.4	0	0	70	93.8
Y plots					
Honeysuckle	0.7	0	0	0	1
Hazel	11.6	0	0	69	89
Oak	22.2	0	25	95	100

7.2.3 Discussion

This section is the first presentation of species records from GMEP across both broadleaved and coniferous woodland, with emphasis on non-natives and on plant species that support fauna (e.g. pollinators and dormice). Key messages are:

1) Broadleaved woodlands support almost twice the species richness of coniferous woodlands at the 2x2m scale considered. The difference in the species richness of butterfly food plants and nectar forage plants is of a similar magnitude.
2) Non-native understorey plant species occurred occasionally in both broadleaved and coniferous woodlands, but more frequently in coniferous woodlands (~8% as opposed to ~2-4%). About 1% of all woodland plots contained *Rhododendron*. Cover of the invasive non-natives considered was around 2% across both woodland types.
3) Dormouse indicators species were generally rare, with oak, hazel and honeysuckle each usually absent from a given broadleaved woodland plot. *Rubus fruticosus* occurs more consistently and is distributed quite evenly among broadleaved and coniferous woodlands. This is also an important flowering plant for pollinators.

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