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Abbreviations Used in this Report

AES	Agri-Environment Scheme
CS	Countryside Survey
GMEP	Glastir Monitoring & Evaluation Programme
QA	Quality Assurance
QC	Quality Control
UKCEH	UK Centre for Ecology & Hydrology

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1 SUMMARY

This annex sets out an overview of the methods and additional results associated with sections 5.1-5.3 of ERAMMP Technical Annex-105TA1 (Emmett et al., 2025).

Additional detail of the methods used can be found in:

- ERAMMP Technical Annex-105TA1S1: Wales National Trends and Glastir Evaluation. Supplement-1: Data Analysis Methods (Jarvis et al, 2025)
- ERAMMP Document-51: Field-Survey Handbook (Procedures) - Soil Sampling (Robinson et al., 2023)
- ERAMMP Document-49: Field-Survey Handbook (Procedures) - Vegetation Plots (Smart et al., 2023)

For additional information about the results in ERAMMP Technical Annex-105 sections 5.1-5.3 please see:

- ERAMMP Technical Annex-105TA1S8: Wales National Trends and Glastir Evaluation. Supplement- 8: Peatland
- ERAMMP Technical Annex-105TA1S9: Wales National Trends and Glastir Evaluation. Supplement- 9: Soil Erosion (Feeney, C. 2025)
- ERAMMP Report-70 – Use of remote sensing to assess soil erosion, poaching & disturbance features (Tye et al., 2023)
- ERAMMP Report-71- Field-Survey Handbook (Procedures) - Soil Erosion and Damage Recording 2021 (Robinson et al., 2021).

2 METHODS

2.1 Soil Processing and Data QA

2.1.1 Soil Processing

Within each of the resampled original 300 x 1-km^2 squares from the GMEP survey (2013-16), a set of soil samples are taken from up to 5 pre-determined, randomly dispersed locations that were established in the previous monitoring campaign. The soil sample analysed for soil metrics is taken using a black plastic core (C-core, Figure 2-1), 15 cm long, from a location co-incident with vegetation surveys. For more detail on soil sampling procedures, see ERAMMP Report 71 – Field Survey Handbook: Soil Sampling. After collection, the soil cores are stored in a refrigerator until being posted, usually within a couple of days, to laboratories at the UK Centre for Ecology & Hydrology, Bangor and Lancaster. An overview of numbers of squares visited, and numbers of samples taken is shown in Table 2-1.

Soil samples taken in 2021 and 2022 were either taken by a botanical survey team, mappers, or soil surveyors. Therefore, for 2021 and 2022, soil and vegetation data are not always co-sampled by the same team. However, robust plot-relocation methodology allows confident co-location of samples even if not sampled at the same time. In 2023, all soil samples are taken at the same time as the vegetation survey was carried out. The ERAMMP soil sample flow for different analyses is shown in Figure 2-1.

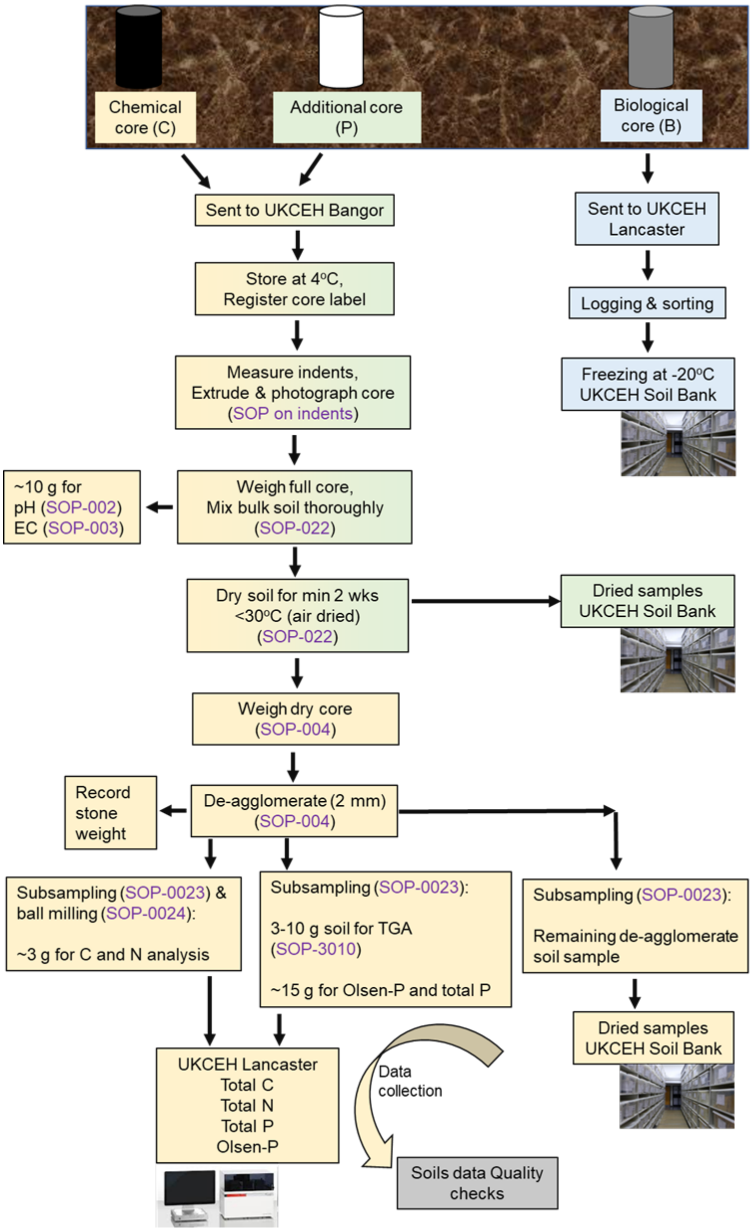

Figure 2-1 ERAMMP soil core flow chart. Chemical cores are used for soil indicator collection, where SOP indicates the Standard Operating Procedure adhered to and TGA stands for Thermo-Gravimetric Analyser.

Table 2-1 Location of sampling point in relation to 2 m x 2 m vegetation quadrat each year. GMEP: Glastir Monitoring and Evaluation Programme (baseline survey of the Welsh landscape), ERAMMP: Environment and Rural Affairs Monitoring & Modelling Programme (first re-survey of the Welsh landscape); number of squares visited each year and number of soil samples analysed.

Year	Project	Sample corner	Number of squares visited	Number of soil samples analysed
2013	GMEP year 1	15 cm to South	60	300
2014	GMEP year 2	15 cm to South	90	450
2015	GMEP year 3	15 cm to South	75	375
2016	GMEP year 4	15 cm to South	75	376
2021	ERAMMP year 1	15 cm to West	124	530
2022	ERAMMP year 2	15 cm to West	5	20
2023	ERAMMP year 3	15 cm to West	95	357

2.1.2 Quality Assurance

Pre 2020, soil data QA was performed by laboratory staff in (version-controlled) Microsoft Excel files. Cleaned data were released to the analyst who checked records against lab books. Data were checked for corelations where expected, to determine outliers. Samples were re-analysed if needed. Thereafter, data were released to the data analysis team.

Soil data collection and processing for UKCEHs large-scale field surveys has undergone multi-step Quality Assurance (QA) since 2020. QA is carried out during and following data-processing by the relevant laboratories. UKCEH laboratory staff and data scientists have developed a workflow to ensure the highest possible soil data standard. Where possible, QA checks and derived variable calculation was automated to ensure consistency and efficiency. However, the results of all QA and derived calculations are manually assessed. A brief description of the QA checks and data management that were performed are described below.

2.1.3 Field data QA

Data collected by surveyors in the field is inspected for data entry errors and missing values. If meta-data is missing field surveyors are contacted to correct this where possible. Comments made by surveyors in the field are stored electronically with sample meta-data from the field. Data collected by the field teams is provided to the labs and analyst staff to support data interpretation. Barcodes and sample IDs are recorded against all electronic meta-data collected in the field and applied to physical samples prior to postage to the labs to enable the tracking of the soil samples.

2.1.4 Lab data QA

All data generated via the labs is run through an automated process that checks for data continuity between the soil sample expected in the lab and the field, identifies formatting errors and flags suspected data entry mistakes where values are outside of expected ranges. The data is assessed against a series of pre-agreed and defined Quality Assurance (QA)standards, developed by the team, using an R script. Any records that do not meet these standards are automatically flagged for review in the output report. It also generates graphics and data summaries to facilitate data inspection, using known value distributions and relationships between soil metrics to allow laboratory staff to identify outliers. These checks are run using an R-script, which runs checks on the lab soil database and saves a summary report (.HTML) containing all information for internal record keeping. This report is then used to verify or improve data quality by lab staff and checks are carried out multiple times whilst data is being processed. If there are any issues that are outside the labs responsibilities to resolve (e.g. surveyor notes that do not match a physical soil sample), then these can be raised to the wider soils team for resolution.

The labs also perform additional QA to ensure measurements are reliable. All cores are photographed prior to any other data processing to provide a reference for subsequent analysis and QA:

- For soil pH and electrical conductivity: Two different internal standards of known pH values were included in each batch. Readings were acceptable only when the measured pH for the internal standards varied within ±2 standard deviations of the mean value. We included in each batch a suitable number of duplicated samples (about 10% of repetitions).

- For Hygroscopic water content, LOI and calcite Quality Control (QC) checks were carried out using internal soil standards prepared in an identical manner to the sampled soils, also a sample of pure calcite was run with each run. Two different internal standards were included in each sample batch. Batches were repeated for which the measured LOI for the internal standards varied by more than 2 standard deviations in either direction from the mean value generated historically for the internal standards. In addition, $CaCO_3$ recovery was within 95-100%, if less than 95% it was repeated.
- For bulk density: Quality control is achieved by using fix volume pre-cut sleeves for soil sampling and extensive training for soil surveyors.
- For Olsen-Phosphorus: Two QC reference samples, a duplicate sample and two blanks are run every 25 samples to ensure data quality. The final concentration is expressed mg kg^{-1} and is corrected for moisture content, the concentration of the blank and using a calibration curve of the standard.
- For total carbon and nitrogen: Quality control is achieved by use of two in-house reference materials analysed with each batch of ~20 samples. The instrument's calibration was checked on use using a working standard (Acetanilide) with a concentration of 71.1% total carbon and 10.4% total nitrogen, and the sample data corrected (factored) against this value. Two of these standards were analysed at the beginning of every run, with every ten samples and again at the end of the run.
- For total phosphorus: Calibrations were run using standards, prepared from blank matrix digested in the same manner as the samples, using the range 0-2 mg L^{-1}, with control standards analysed every ten samples to check precision and reproducibility throughout the run. Blanks and reference samples to assess the chemistry and the digest were run with each batch. The data is corrected for moisture content and reported in mg kg^{-1} phosphorus.

Should any changes or follow-up checks be made to the data (e.g. correcting data entry, re-processing a sample to verify an outlying measurement) this is recorded against the data record to facilitate subsequent data processing and quality assurance and provide a clear audit trail.

2.1.5 Soil derived metrics

Data provided from the labs and measurements taken in the field are processed into the derived variables required for analysis and subsequent QA (e.g. core volume, bulk density, organic carbon content, porosity and for ERAMMP also average organic layer depth).

Prior to 2020, calculations were performed in Microsoft Excel. The definition of these calculations was transcribed into an R file and is now stored separately from the R script used to derive them. This helps protect the calculations from accidental changes through repeated use. In addition, this script is used to pull in supporting information from analysis from paired sites in the vegetation survey using the shares IDs. This process outputs a formatted version of both direct laboratory measurements, derived metrics, field meta-data, supporting data from the co-located vegetation survey and all comments from prior data processing that is in principle analysis ready, subject to the final data quality checks.

2.1.6 Analyst data QA

Prior to data released for analysis, a final detailed data inspection is carried out over the derived and raw data. The data is assessed against a series of pre-agreed and defined quality assurance standards, developed by the team, using an R script. Any records that do not meet these standards are automatically flagged for review in the output report. In addition, the report generates graphical summaries for all analysed metrics that show:

- The distributions of each metrics
- How the data conforms to expected relationships between variables (e.g. C:N ratio)
- How the data conforms to expected relationships between variables, for different pH ranges, organic matter contents, soil types and board habitats (e.g. the relationship between porosity between organic matter content and broad habitat).
- The level of agreement or change between current measurements and any previous measurements recorded for that site, for all analysed metrics, by broad habitat.

These summaries enable analysts to inspect values in detail and in context. Unusual or anomalous measurements can be identified and evaluated to determine the source of the issue. At this stage, data analysists closely work with the labs to understand any outstanding data queries arising. If necessary, samples can be reprocessed by the labs to determine whether values are reliable. Any changes made to the data are recorded against the relevant data record to maintain an audit trail.

2.1.7 Spatial data QA

The location of soil samples is recorded in the field for each sampling site (see Smart et al., 2023). These locations are inspected for data entry errors. For subsequent analyses, it is important to ensure that each sample is relocated in time according to the plot-relocation protocol. As such, additional quality assurance checks are performed using information provided by the surveyors, the recorded locations of plots, photographs of the sampling sites and plot relocations maps to ensure plots were sufficiently relocated. Through this process a new ID system is assigned that explicitly matches samples to the samples taken at the same location. If a plot has not been relocated, that plot is assigned a different ID compared to samples previously taken at that plot. This repeat-plot-id was created after the first re-survey (ERAMMP) and is used in subsequent modelling. As some visits from the soils and vegetation teams to the same plots were separate - and therefore required a plot to be relocated twice - repeat plot IDs were also evaluated and assigned for each visit, where genuine repeats were assigned the same ID, as above.

2.2 Habitat Classification for Soils

All soil sample locations have a broad habitat allocation recorded for that site in the field during the vegetation survey. Broad habitat is assigned based on the habitat coverage of the area surrounding the X-plot that corresponds to the minimum mappable area for habitat mapping in the original field survey (2013-16). Where soil and vegetations visits were carried out by sperate teams, both of whom recorded the present broad habitat, we checked that both broad habitat entries agreed. If there was a disagreement on the broad habitat between the habitat assignment despite both teams visiting the same site, priority was given to the assignment from the vegetation surveyors, as they have a higher level of botanical training, after comparing assigned classes to plot photos and checking for data entry errors. On the rare occasion where only soils were surveyed, the broad habitat assignment from the soil surveyor was used. In cases where the soil surveyors or botanists assigned Arable and Horticultural Land, the information given by the soil surveyor was used. For more information on broad habitat assignments see ERAMMP Technical Annex-105: Wales National Trends and Glastir Evaluation. Supplement-2: Broad Habitat Results (Emmett et al., 2025) and Smart et al., (2023).

2.3 Glastir Definition for Soils

Information of Glastir coverage was extracted for all unique soil sample points (see Section 2.1 Spatial QA and the description of repeat plot IDs). Despite plots being accurately relocated, there is often small disagreement between the recorded latitude and longitude for the plot on each visit. Therefore, to simplify the data extraction process, coordinates for the first visit to a plot were used for all visits when a repeat plot ID was shared. Data extraction was also performed using the coordinates for the latest visit to all plots and it was found that the choice of location impacted the detection of less than 10 action – site combinations across the entire dataset of over 2750 action-site matched (< 0.3% of matches).

Glastir options were considered present at a site if a site of management intersected with the recorded soil sample point. This approach was chosen for two reasons:

- Soils are unlikely to be responsive to managements applied to the surrounding area (as compared to water quality or pollinator diversity, for example).
- A trail of data extraction using a 100 m buffer around soil sample sites was performed and no difference in bundle membership across soil sample sites was detected, and so the simpler option was chosen. Note: This will be less likely to be true for other vegetation plot types in ERAMMP, particularly when targeting boundary features.

A Glastir bundle was present if any action within that bundle occurred at the site within the relevant time frame. For the baseline visit (2013-16) we considered actions present between the start of Glastir (2012) up to and including the year of sampling. For subsequent visits, we considered actions present since the previous sample (non-inclusive), up to and including the year of the current sample.

Data was also extracted for the presence of historic agri-environment schemes (AES; Tir Cynnal and Tir Gofal). The presence of historic AES schemes was defined in the same fashion as Glastir, with the exception that the relevant timeframe was considered to be any year. As such, if a site was subject to historic AES management in the baseline survey, it would also by definition have been present for subsequent surveys. For additional context and information on Glastir data see the ERAMMP Technical Annex-105TA1S1: Wales National Trends and Glastir Evaluation. Supplement-1: Data Analysis Methods (Jarvis et al., 2025).

2.4 Modelling Approach

For full detail on the modelling approach used for data analyses in ERAMMP, see Jarvis et al. (2025). However, we have described additional specifics for the soils analysis modelling approach below.

Models are implemented in R using the glmmTMB package (Brooks et al, 2017). This package allows a wide range of error distribution and random effect structures to be fit and is computationally fast to run.

Across the soils indicators and habitats considered in the analysis, the model distribution was variably set as one of a Gaussian, log-normal or Tweedie distribution based on an assessment of the data distribution and model fits. In some cases, outliers were found that caused models to report significant trends that were not present in the absence of the outliers. Where this was the case, we report model results with the outliers removed. In some cases, the presence of extreme outliers prevented model convergence. These outliers were also removed, where they represented a small proportion of the overall dataset (maximum of 10 data points), in order to allow to report on wider trends.

2.4.1 National Trend

For National trends, the Fixed effect was “SURVEY”, defining the time frames 2013-16 and 2021-2023. Random effects were SQ_ID/RPT_PLOT_ID, with SQ_ID defining the square in which the sample was taken, and the RPT_PLOT_ID define the samples which were taken in both surveys. One model was run for each soil health indicator for each habitat.

2.4.2 Glastir Analysis

For the Glastir trend analyses it was first assessed how many sites had taken up different Glastir options and historic agri-environment (AES) schemes. We also plotted the actions within the representative bundles to understand the expected effect of bundles on the soil health indicators. Glastir bundles with enough uptake for an analysis were incorporated into the model as fixed effects in the form of SURVEY * bundle. If more Glastir bundles and / or historic AES was present, these fixed effects were added as e.g. SURVEY * bundle1 + SURVEY * historic AES. SURVEY was defined as the time frames 2013-16 and 2021-2023 in the same way as for the national trend models. Random effects were SQ_ID/RPT_PLOT_ID, with SQ_ID defining the square in which the sample was taken, and the RPT_PLOT_ID define the samples which were taken in both surveys. One model was run for each soil health indicator for each habitat. Effects of Glastir and / or historic AES was captured. Glastir models were not run when only historic AES was present with sufficient uptake but Glastir was not.

Notes on Long-Term Trends

Along with national trends from 2013-16 to 2021-23, we also provide tabulated information on long term historic trends by broad habitat where available, using data from the Countryside Survey (CS) for Wales. Data were extracted from Emmett et al. (2010). This dataset covers changes in soil condition from 1978 or 1998 to 2007, depending on the soil indicator considered. Topsoil indicators in Countryside Survey were measured across a smaller number of sites relative to the GMEP (2013-16) and ERAMMP (2021-23) sampling programs. Despite a compatible sampling approach being used across programs to enable comparison, the difference in sampling effort resulted in the Countryside Survey soil samples being from a higher latitude on average, when compared to subsequent monitoring campaigns. Therefore, directly comparing means from the Countryside Survey for Wales to those published here for 2013-16 and 2021-23 may be misleading.

To understand change in soil condition from the Countryside Survey to 2013-16, readers should consult the GMEP report (Emmett et al., 2017) which explicitly examined change by tracking the same sites across both populations. As a result of this modelling approach, mean estimates for Wales and broad habitats in the GMEP report may differ to those reported here, as they are partially influenced by the historic dataset. National and habitat means estimated using only the 2013-16 and 2021-23 surveyed (this report) are considered more representative of Wales.

3 RESULTS

3.1 Wales

3.1.1 Distributions and thresholds

Topsoil indicators and their responses are closely linked (Seaton et al. 2021, Emmet et al. 2010). Topsoil carbon and nitrogen concentrations decrease with increasing topsoil bulk density in a distinct curve-shaped relationship (Figure 3-1A and B). High topsoil acidity is linked to highest topsoil carbon concentrations (Figure 3-1 C). Topsoil carbon and nitrogen concentrations are tightly linked at lower concentrations especially in Arable and Horticultural land and Improved Grassland, with variation increasing with higher concentrations in unmanaged habitats (Figure 3-1 D).

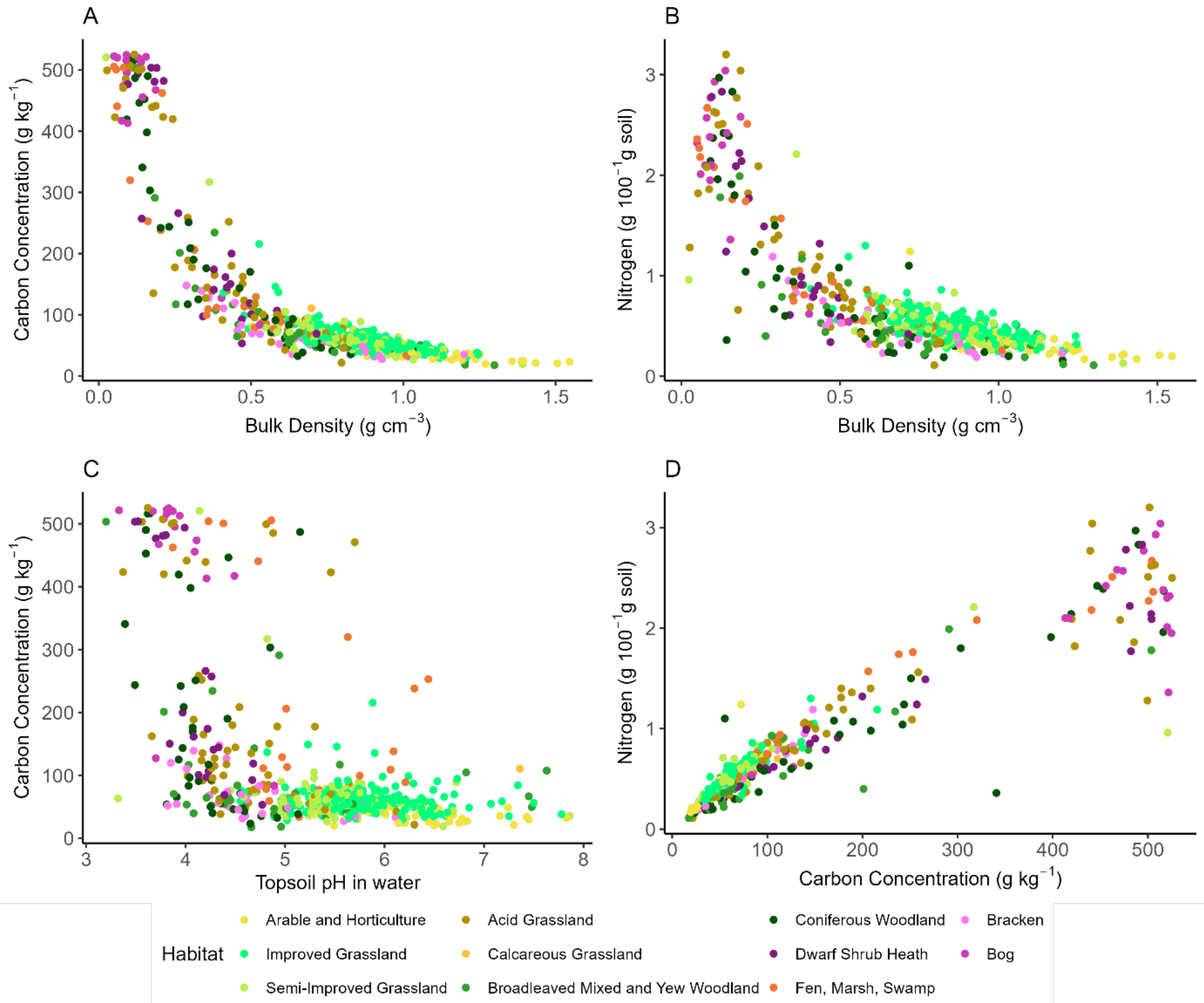

Figure 3-1 Relationships between topsoil metrices across different habitat classes in 2021-23. A) topsoil bulk density and carbon concentration, B) Topsoil bulk density and nitrogen concentration, C) topsoil pH and carbon concentration, and D) Topsoil carbon concentration and nitrogen concentration. Visualisation similar to Seaton et al. 2021.

Across Wales, topsoil carbon density increased from on average 64.9 t C ha^{-1} in 2013-16 to 69.4 t C ha^{-1} in 2021-23. This increase in topsoil carbon density was caused by an increase in topsoil bulk density from on average 0.63 g cm^{-3} in 2013-16 to 0.68 g cm^{-3} in 2021-23.

Topsoil bulk density was highest in Arable and Horticultural land with an average bulk density below the critical threshold of 1.3 g cm^{-3} for environmental protection and habitat support (Merrington et al. 2006, upper grey line in Figure 3-3). With an average bulk density of 1.09 g cm^{-3} and the upper confidence interval of 1.17 g cm^{-3}, Arable and Horticultural land is at risk of bulk densities crossing the critical threshold. Topsoil bulk densities in Improved and Semi-Improved Grasslands remain well below the threshold of 1.3 g cm^{-3}. For peaty soils, the critical bulk density threshold for good environmental protection and habitat support is 1.0 g cm^{-3} (Merrington et al. 2006). For habitats on peaty soils (Figure 3-7), Coniferous Woodland and potentially the Bracken habitat are approaching critical bulk densities.

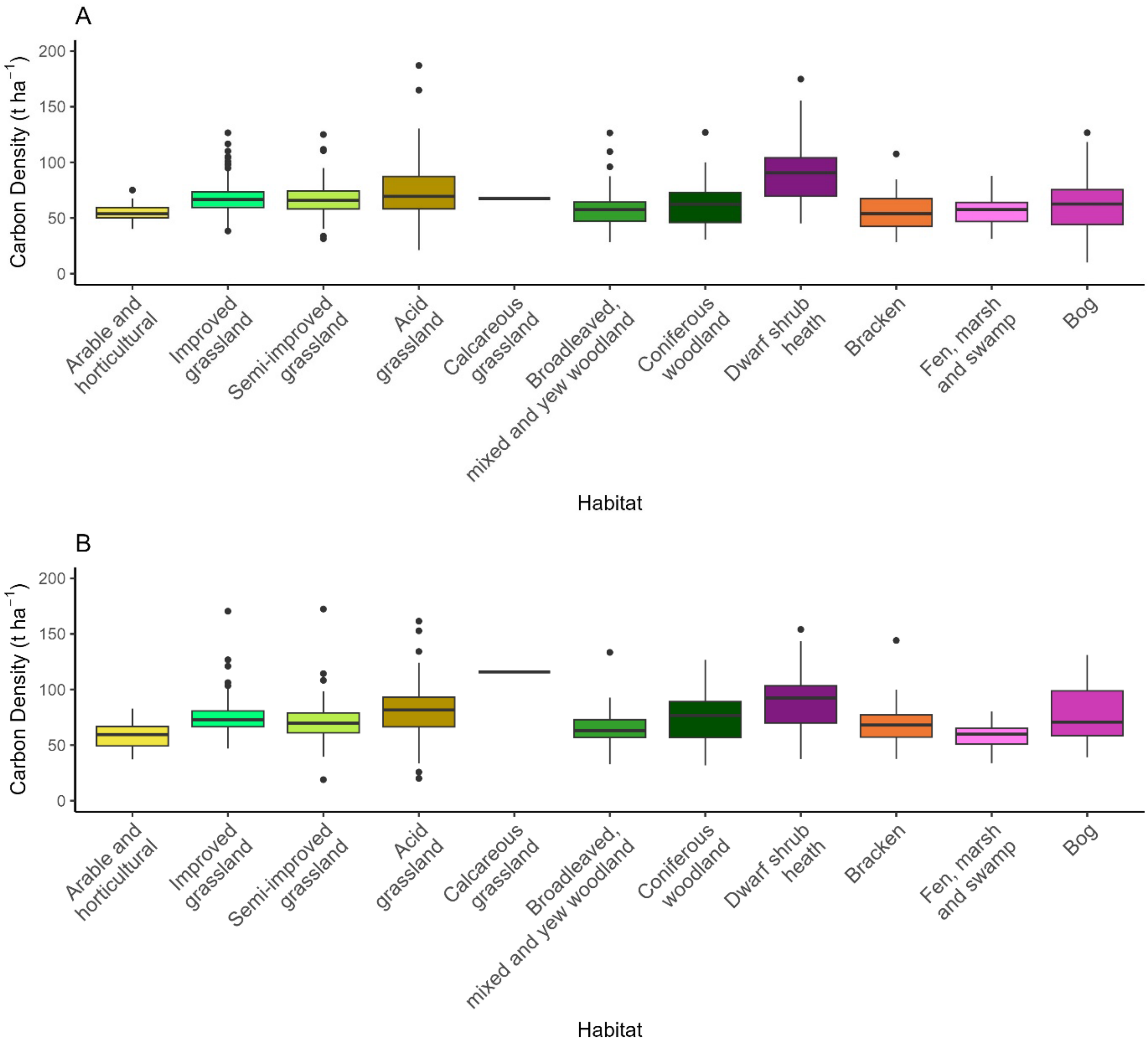

Figure 3-2 The difference in topsoil carbon density across different habitat classes. A) 2013-16 and B) 2021-23. The horizontal lines indicate the midpoint, the boxes indicate where the mid 50% of all values sit and the vertical lines represent the full range of values observed.

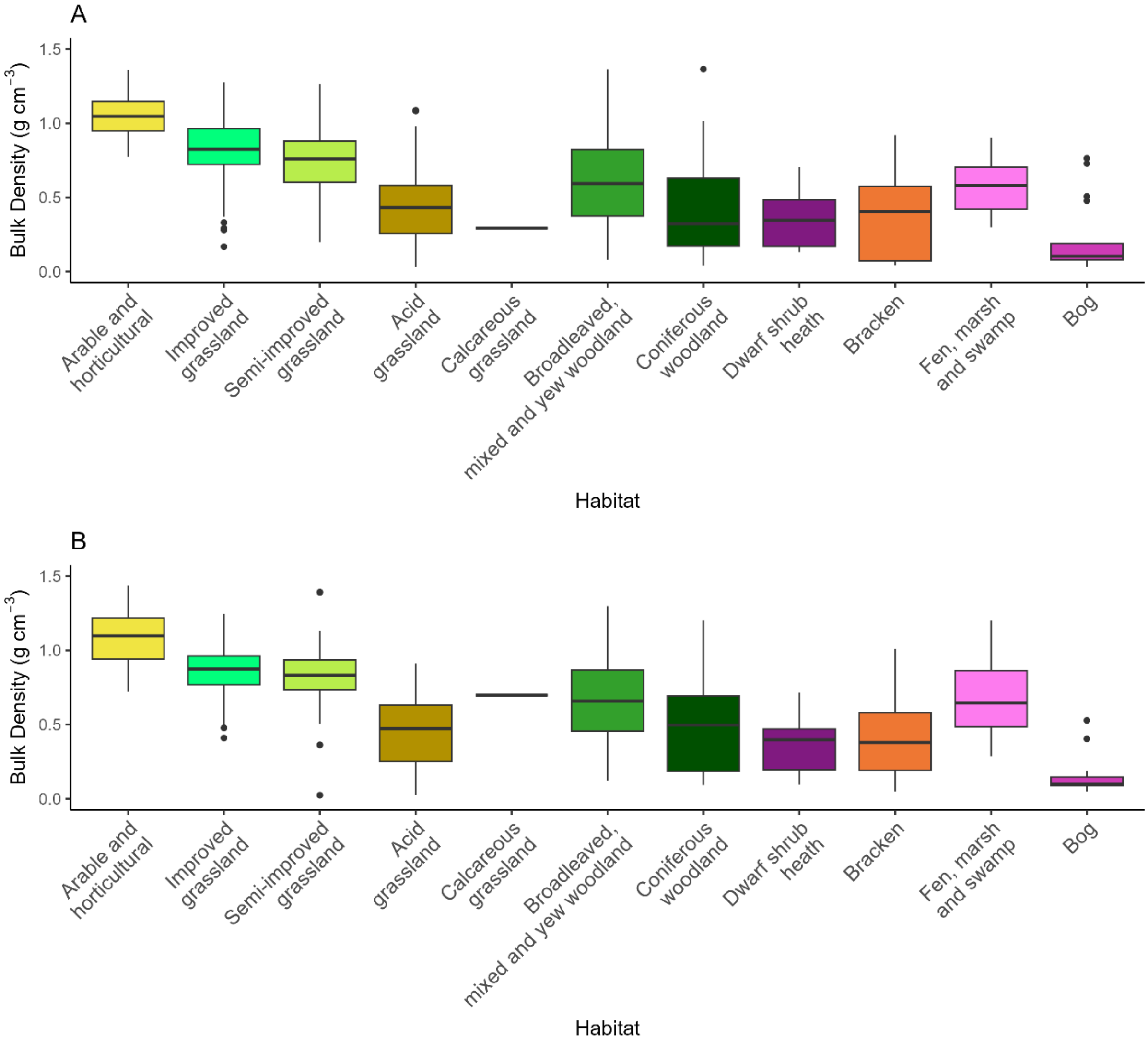

Figure 3-3 The difference in topsoil bulk density across different habitat classes. A) 2013-16 and B) 2021-23. The horizontal lines indicate the midpoint, the boxes indicate where the mid 50% of all values sit and the vertical lines represent the full range of values observed.

Topsoil carbon concentration remained stable across Wales with an average of 81.8 g C kg^{-1} in 2013-16 and 80.4 g C kg^{-1} in 2021-23. The lowest topsoil carbon concentrations were found in Arable and Horticultural land, Improved Grassland and Semi-Improved Grassland, and also in Fen, Marsh and Swamp and Broadleaved Mixed and Yew Woodland (Figure 3-4). Lowest topsoil carbon concentrations were found on land with no, or only a few sites showing a peaty layer (Figure 3-7). High in-habitat variation of topsoil carbon concentration was observed for habitats showing variable peat depth, with the highest topsoil carbon concentrations found in Bog as expected. Topsoil nitrogen concentrations followed a similar pattern to topsoil carbon concentrations (Figure 3-6).

Topsoil pH has decreased from on average 5.37 in 2013-16 to 5.33 in 2021-23. This small but significant decrease in topsoil pH across Wales is in line with findings observed across GB (Seaton et al. 2023). Topsoil pH tended to be higher on manged land (Arable, Improved and Semi-Improved Grassland) (Figure 3-5). Acid Grassland, Broadleaved Woodland, Bracken and Fen habitats tended to have higher pH than Bog, Dwarf Shrub Heath and Coniferous Woodland.

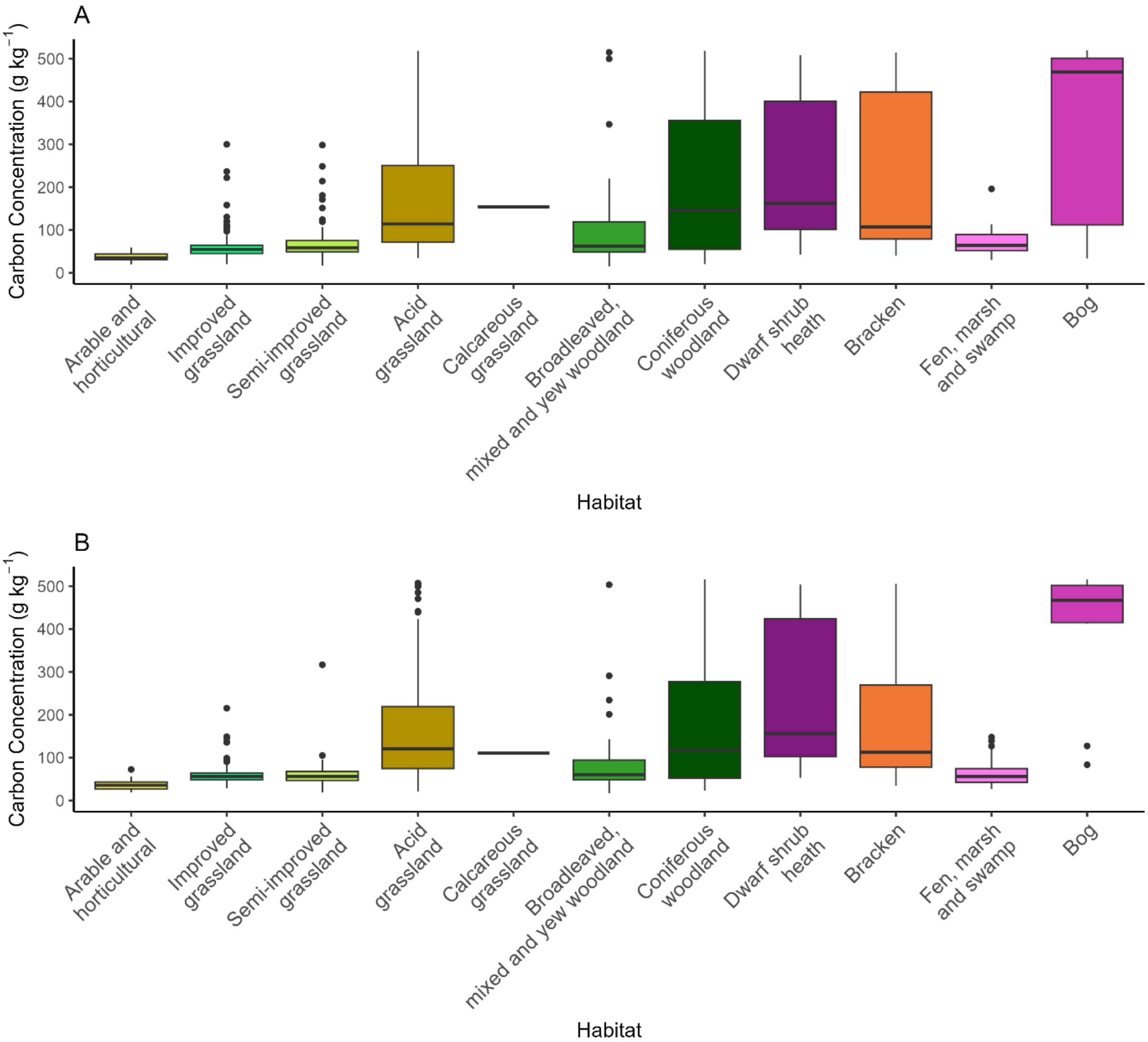

Figure 3-4 The difference in topsoil carbon concentration across different habitat classes. A) 2013-16 and B) 2021-23. The horizontal lines indicate the midpoint, the boxes indicate where the mid 50% of all values sit and the vertical lines represent the full range of values observed.

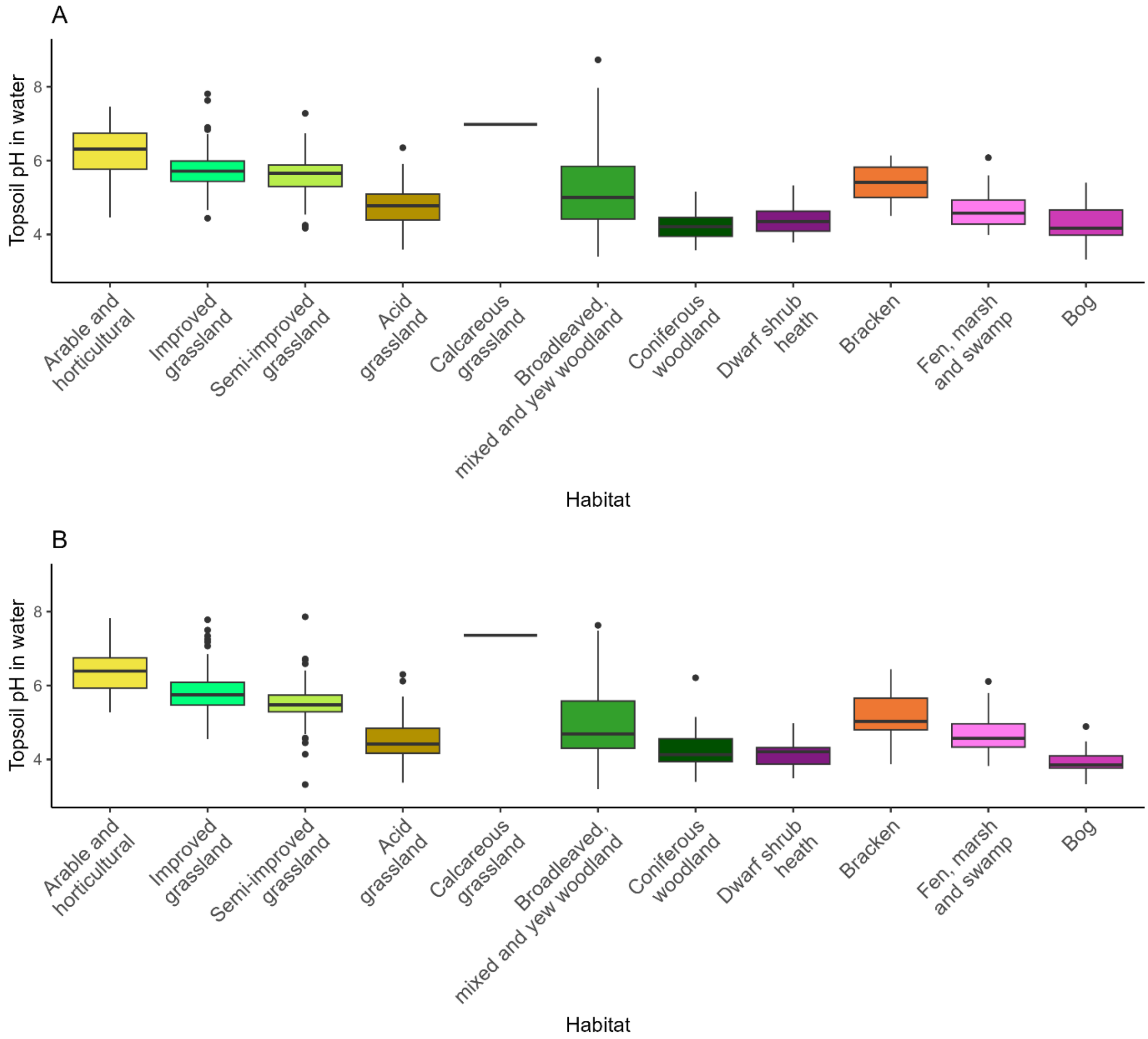

Figure 3-5 The difference in topsoil pH across different habitat classes. A) 2013-16 and B) 2021-23. The horizontal lines indicate the midpoint, the boxes indicate where the mid 50% of all values sit and the vertical lines represent the full range of values observed.

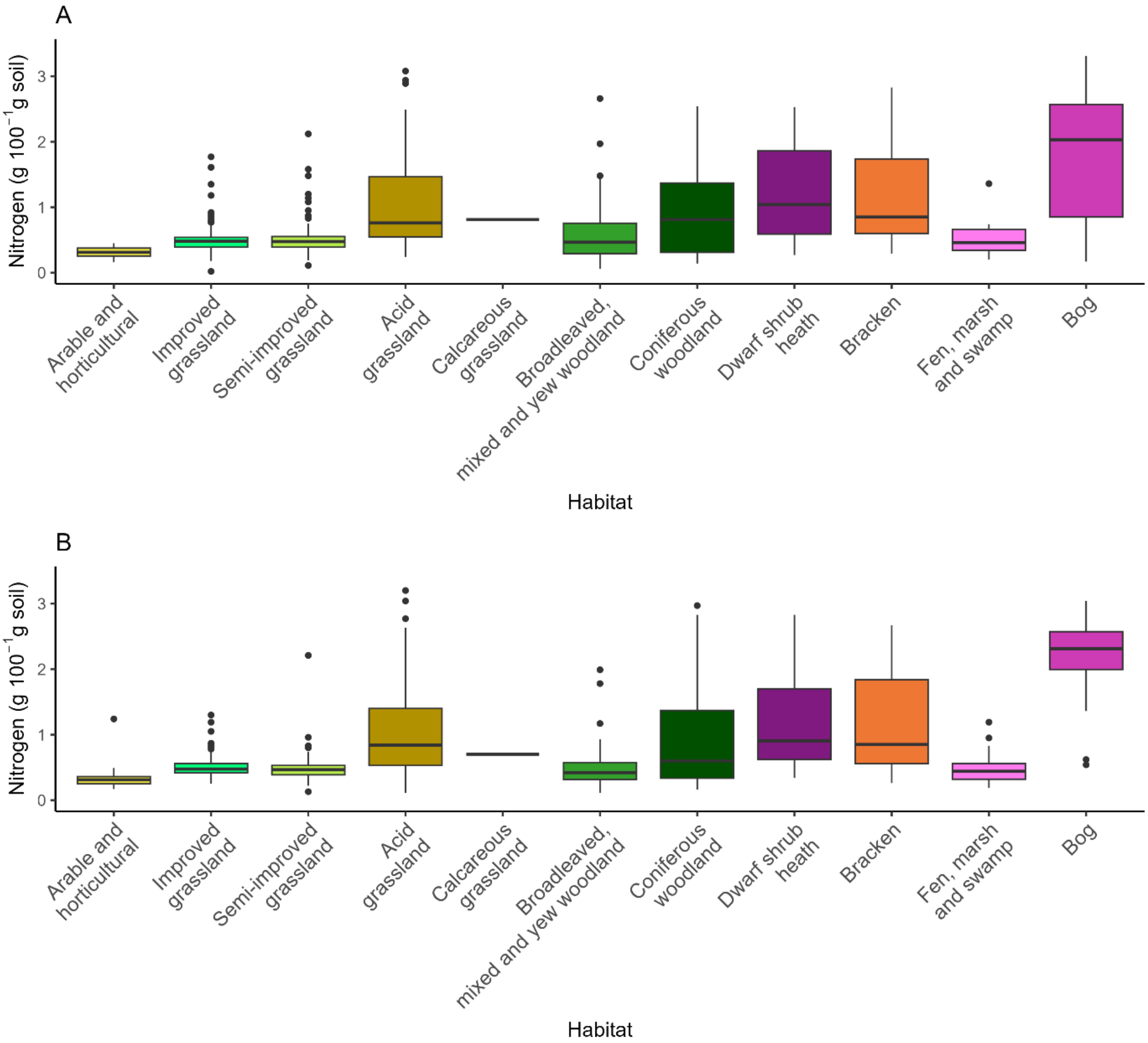

Figure 3-6 The difference in topsoil nitrogen concentration across different habitat classes. A) 2013-16 and B) 2021-23. The horizontal lines indicate the midpoint, the boxes indicate where the mid 50% of all values sit and the vertical lines represent the full range of values observed.

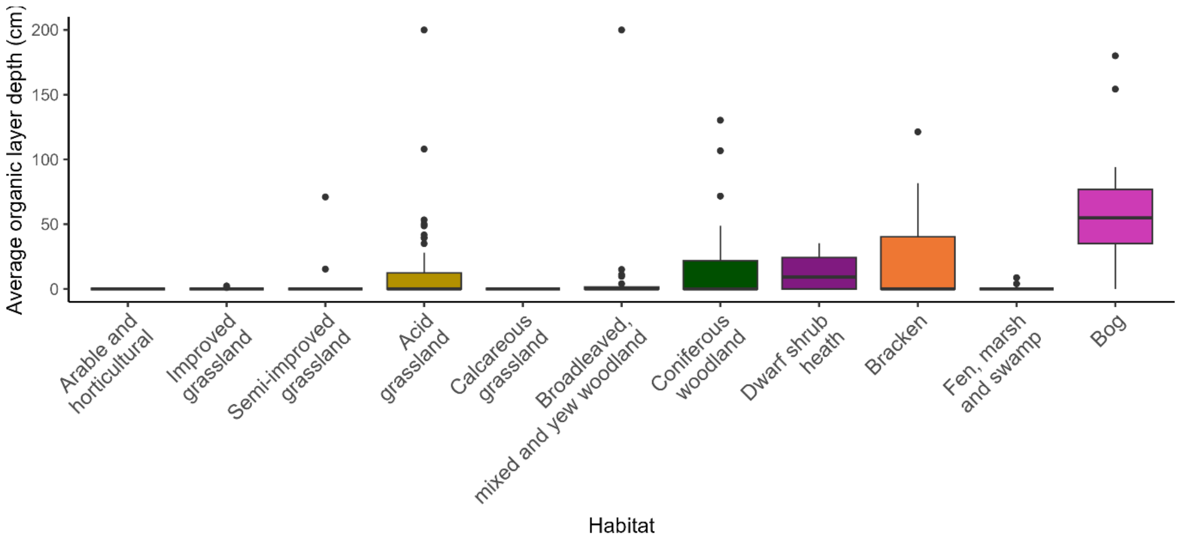

Figure 3-7 The difference in average organic layer depth (cm) across different habitat classes for 2021-23. The horizontal lines indicate the midpoint, the boxes indicate where the mid 50% of all values sit and the vertical lines represent the full range of values observed.

The limit for soils leaching Olsen P is 60 mg kg $^{-1}$ (Bhogal et al. 2008) which the Welsh population is well below on average. The ranges of Olsen P for biomass production in Arable and Horticultural, and Improved Grassland are 16-45 mg P kg^{-1} and 16-25 mg P kg^{-1}, respectively (Merrington et al. 2006). A small number of sites exceed the leaching threshold and will be point sources of pollution, potentially linked to specific activities on specific farms that will need to be addressed. In 2013-16, one plot in Arable and Horticultural land, and 10 plots in Improved Grassland showed Olsen-P values above 60 mg kg^{-1} (Figure 3-8). By 2021-23, the numbers of sites with Olsen-P values above the threshold had more than doubled to 6 and 23 plots in Arable and Horticultural land, and Improved Grassland respectively (Figure 3-8 B). The plot in Arable and Horticultural land, and half the plots showed Olsen-P values above 60 mg kg^{-1} in 2013-16 and 2021-23.

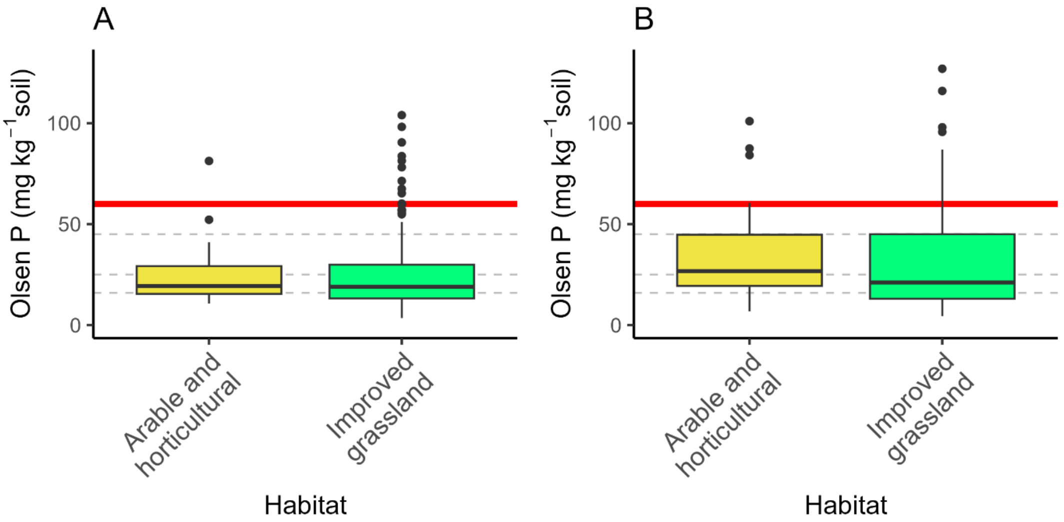

Figure 3-8 The difference in topsoil Olsen phosphorus concentration across Arable and Horticultural and Improved Grassland. A) 2013-16 and B) 2021-23. The red line indicates the 60 mg kg-1 threshold at which leaching occurs. The grey dashed lines indicate upper and lower thresholds for productivity in arable and horticultural systems (16-45 g kg-1) and improved grassland systems (16-25 g kg-1). The black horizontal lines in the boxes indicate the midpoint, the boxes indicate where the mid 50% of all values sit and the vertical lines represent the full range of values observed.

3.1.2 National Trend

Table 3-1 Long-term and short-term trends in topsoil indicators for the Welsh National Trend. Long-term data and trends in indicators for Wales were extracted from Emmett et al. 2010 using the Countryside survey for Wales 1978 to 2007. Data analysis from this report cover the time periods 2013-16 (GMEP) and 2021-23 (ERAMMP). Models were run for each soil health indicator and Mean values, minimum and maximum confidence intervals (CI) were extracted and the mean change estimated. The p-value for the mean change in each soil health indicator is reported. No data are shown as grey boxes.

			Countryside Survey				Trend 1978/98-2007		2013-16			2021-23			Trend 2016-2022	
Asset class	Habitat	Indicator	1978	1990	1998	2007	Mean change	P value	Mean	min CI	max CI	Mean	min CI	max CI	Mean change	P value
Wales	All Wales	Carbon (g/kg, from organic matter)	107.6		108.9	108.6	1.0	>0.05	81.8	74.9	89.3	80.4	73.6	87.9	-1.37	0.196
		pH in water	5.0		5.4	5.6	0.56	<0.05	5.4	5.3	5.5	5.3	5.2	5.4	-0.04	0.041
		N (g/100g dry soil)			0.7	0.7	-0.04	>0.05	0.6	0.5	0.6	0.6	0.5	0.6	0.00	0.809
		Carbon density (tC/ha)	76.5		80.2	75.2	-1.3	>0.05	64.9	63.0	66.7	69.4	67.5	71.5	4.58	0.000
		Bulk density (g/cm3)							0.6	0.6	0.7	0.7	0.6	0.7	0.05	0.000

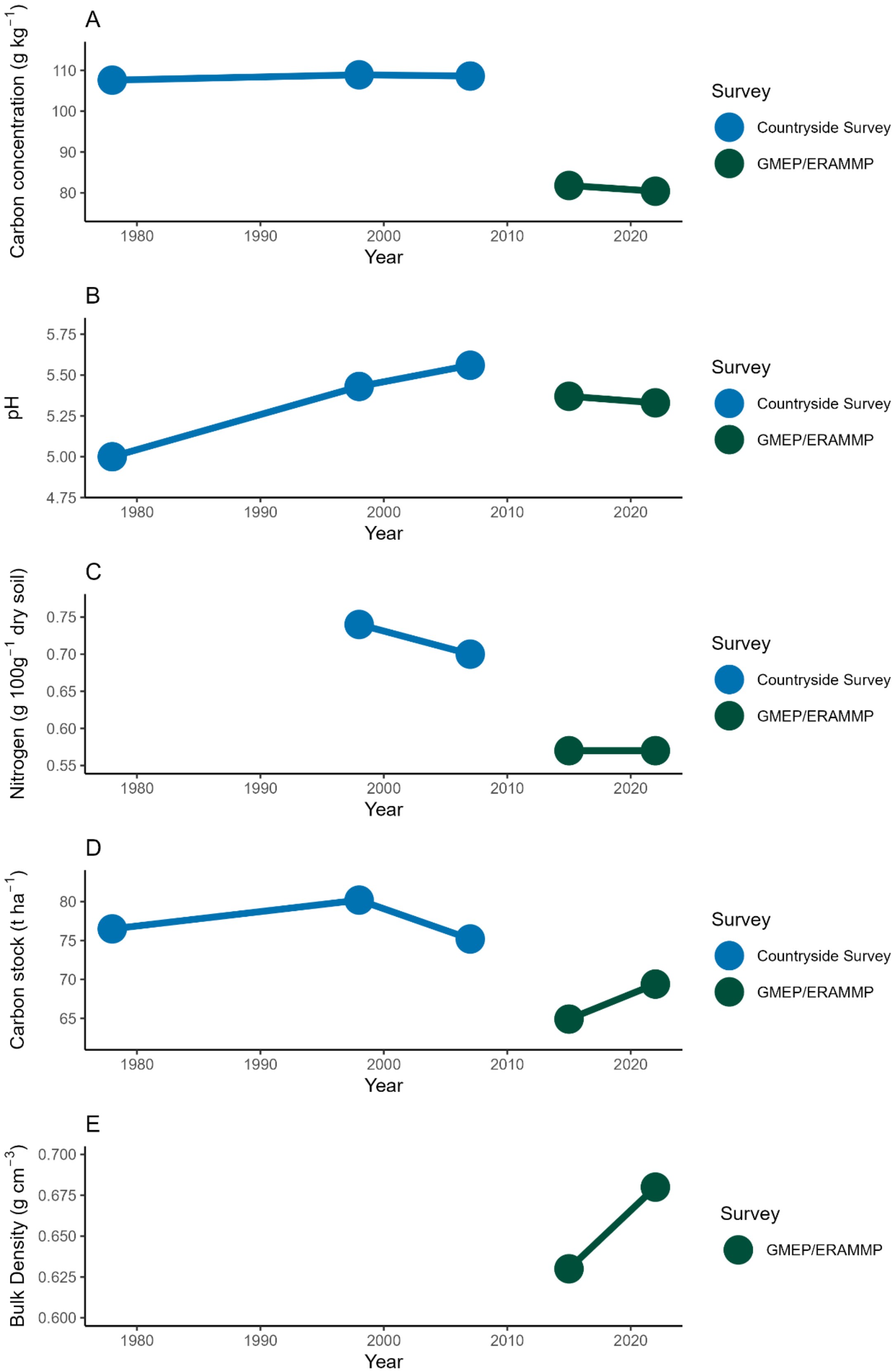

Figure 3-9 Long term national trends in A) Carbon concentration, B) pH, C) Nitrogen, D) carbon stock, and E) Bulk Density from Countryside Survey squares in Wales (1978 to 2007) and GMEP/ERAMMP (2013–16 to 2021–2023) from nationally representative survey squares.

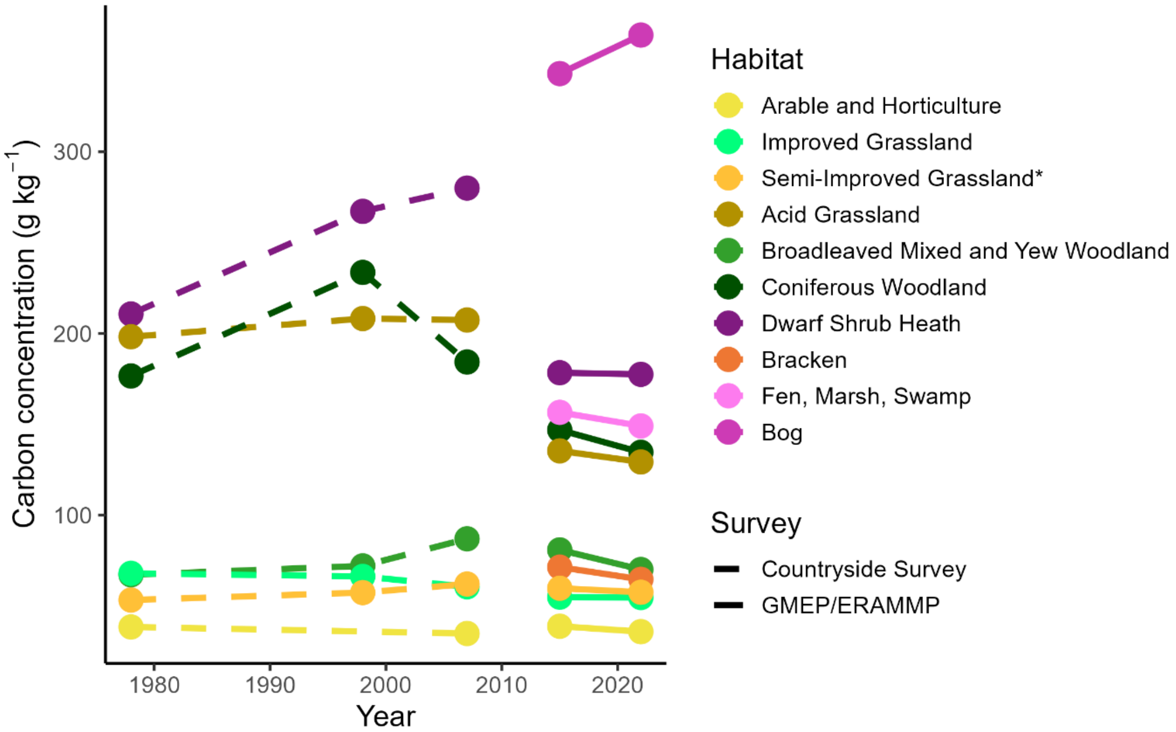

Figure 3-10 Long term national trends in Carbon Concentration in topsoil by broad habitat from Countryside Survey squares in Wales (1978 to 2007) and GMEP/ERAMMP (2013–16 to 2021–2023) from nationally representative survey squares. Semi-Improved Grassland in GMEP-ERAMMP is compared to data for neutral grassland in the Countryside Survey.

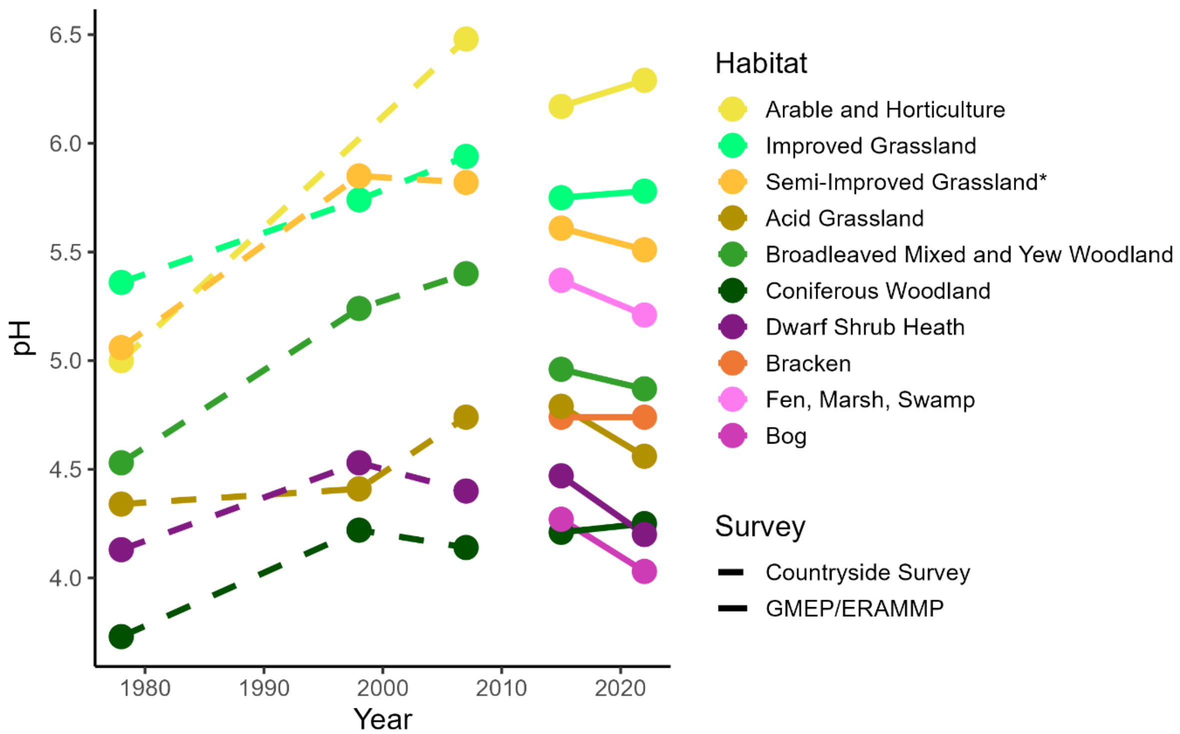

Figure 3-11 Long term national trends in pH in topsoil by broad habitat from Countryside Survey squares in Wales (1978 to 2007) and GMEP/ERAMMP (2013–16 to 2021–2023) from

nationally representative survey squares. Semi-Improved Grassland in GMEP-ERAMMP is compared to data for neutral grassland in the Countryside Survey.

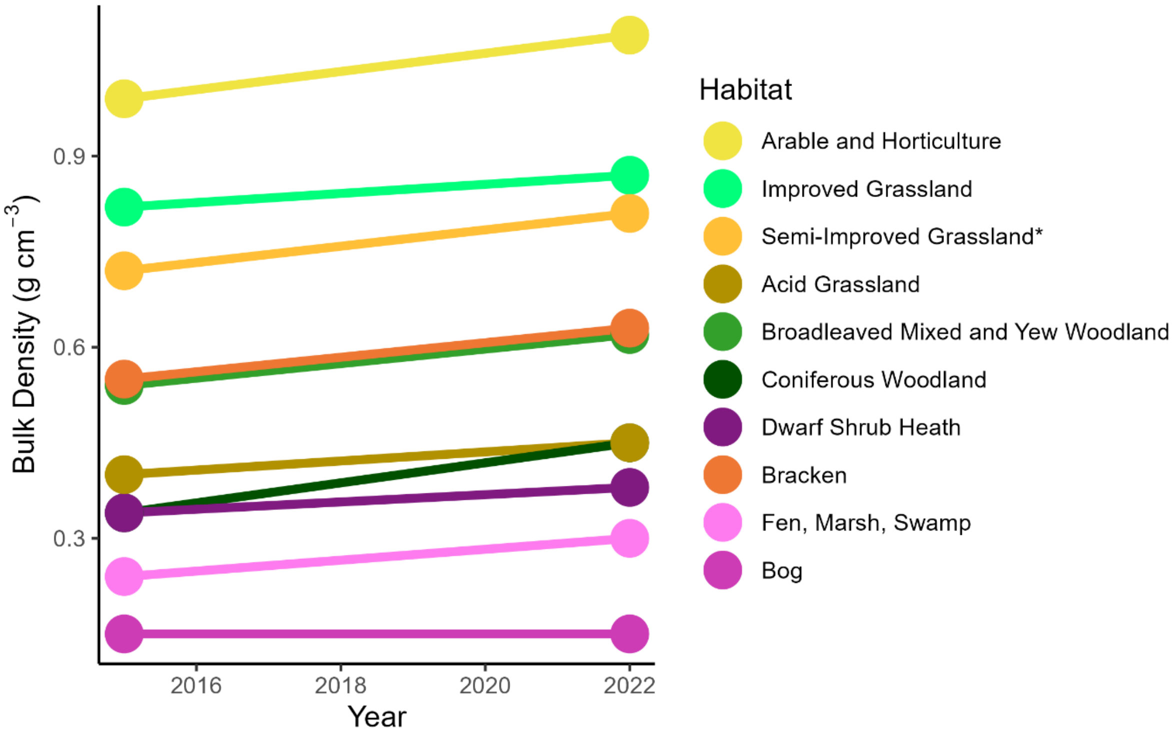

Figure 3-12 National trends in Bulk Density in topsoil by broad habitat from GMEP/ERAMMP (2013–16 to 2021–2023) from nationally representative survey squares.

3.1.3 Glastir Analysis

Table 3-2 Glastir analysis for soil health indicators in Wales. The models test for the effect of Glastir presence compared to no Glastir presence on soil health indicators across the complete data population. The Glastir effect was tested for 2013-16 (GMEP) compared to 2021-23 (ERAMMP). The Glastir effect and the associated P values is reported for each soil health indicator.

		Glastir presence	
Habitat	**Indicator**	**Glastir effect**	**P value**
All Wales	Carbon (g/kg, from organic matter)	0.2	0.820
	pH in water	-0.06	0.120
	N (g/100g dry soil)	0.01	0.770
	Carbon density (tC/ha)	-2.03	0.080
	Bulk density (g/cm^3)	0.0	0.800

4 RESULTS BY HABITATS

4.1 Broadleaved Mixed and Yew Woodland

4.1.1 National Trend

Table 4-1 Long-term and short-term trends in topsoil indicators for Broadleaved Mixed and Yew Woodland. Long-term data and trends in indicators for Broadleaved Mixed and Yew Woodland were extracted from Emmett et al. 2010 using the Countryside survey for Wales 1978 to 2007. Data analysis from this report cover the time periods 2013-16 (GMEP) and 2021-23 (ERAMMP). Models were run for each soil health indicator and Mean values, minimum and maximum confidence intervals (CI) were extracted and the mean change estimated. The p-value for the mean change in each soil health indicator is reported. No data are shown as grey boxes.

			Countryside survey				Trend 1978/98-2007		2013-16			2021-23			Trend 2016-2022	
Asset class	Habitat	Indicator	1978	1990	1998	2007	Mean change	P value	Mean	min CI	max CI	Mean	min CI	max CI	Mean change	P value
Woodland	Broadleaved Mixed and Yew Woodland	Carbon (g/kg, from organic matter)	67.2		72.1	87.0	19.8	>0.05	80.9	62.3	105.0	70.1	53.7	91.6	-10.8	0.015
		pH in water	4.53		5.24	5.40	0.87	<0.05	4.96	4.66	5.29	4.87	4.56	5.20	-0.09	0.324
		N (g/100g dry soil)							0.49	0.39	0.62	0.46	0.36	0.59	-0.03	0.192
		Carbon density (tC/ha)	77.2		61.4	79.0	1.8	<0.05	60.8	55.1	67.0	63.6	57.2	70.7	2.8	0.276
		Bulk density (g/cm3)							0.54	0.45	0.64	0.62	0.51	0.75	0.08	0.025

4.1.2 Glastir Analysis

In Broadleaved Mixed and Yew Woodland, only the Glastir "Woodland Management" bundle had sufficient uptake for analyses, along with membership in past AES schemes (Tir Gofal and Tir Cynnal). All actions coinciding with Broadleaf and Mixed Yew Woodland soil samples in the Woodland management bundle were "Woodland - stock exclusion". Of the soils which were part of historic AES schemes only 36% are now in Glastir, and Historic AES was present in ~25% of the plots on non-Glastir land, compared to ~ 13% on Glastir land.

Table 4-2 Data coverage for the Glastir analysis for Broadleaved Mixed and Yew Woodland. The Glastir Woodland management bundle, and presence in historic AES schemes were analysed. Glastir bundle or historic AES present (0 = no, 1 = yes), and count for combinations for each time point (2013-16 and 2021-23).

Survey	Woodland Management	Context: Historic AES	Count
2013-16	0	0	72
2013-16	0	1	12
2013-16	1	0	1
2013-16	1	1	5
2021-23	0	0	35
2021-23	0	1	9
2021-23	1	1	7

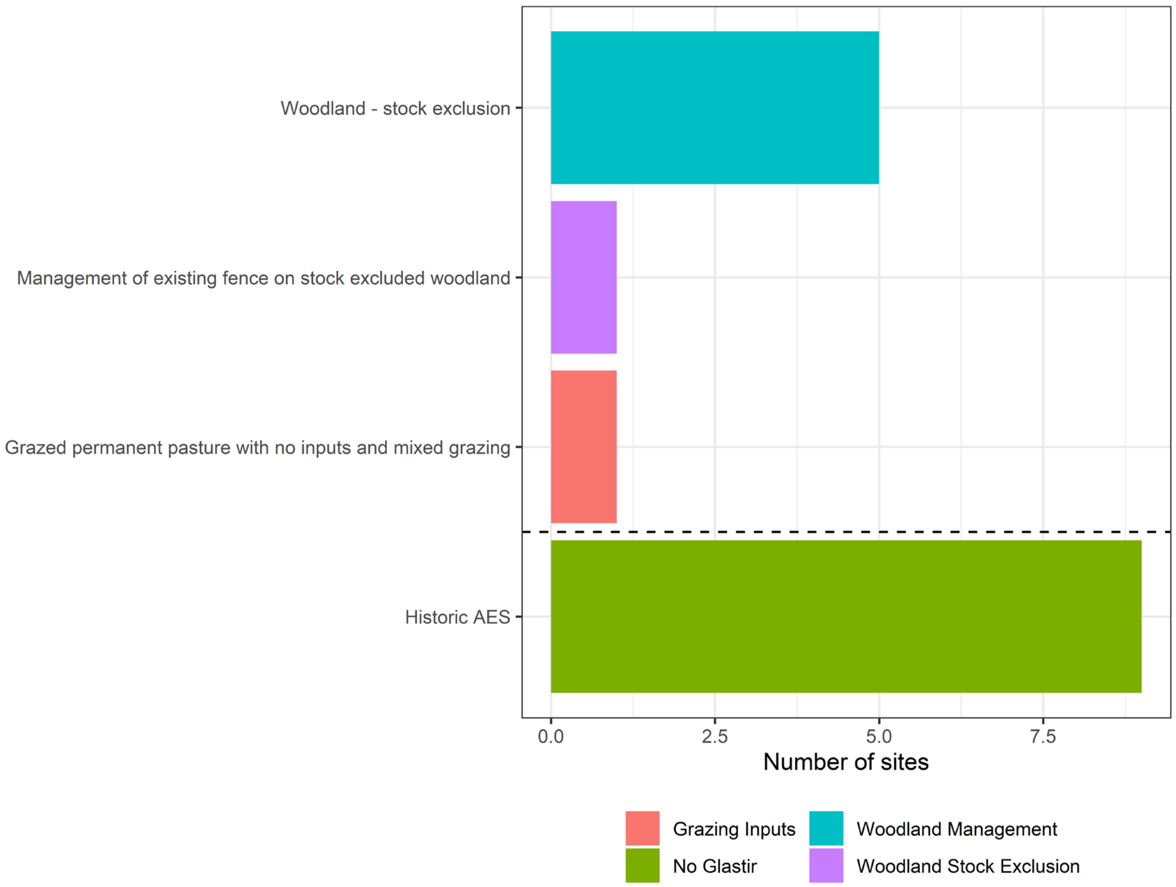

Figure 4-1 Action frequency in Glastir bundles present in resurveyed sites for Broadleaved Mixed and Yew Woodland. The Woodland management bundle contained the action Woodland – stock exclusion only. Other bundles were not tested due to low uptake.

Table 4-3 Glastir analysis for topsoil health indicators in Broadleaved Mixed and Yew Woodland. The models test for the effect of Glastir bundle compared to no plots without the Glastir bundle on topsoil health indicators. Context effect was tested using information related to participation in historic agri-environment schemes (AES). The Glastir and Context effect was tested for 2013-16 (GMEP) compared to 2021-23 (ERAMMP). The Glastir bundle/Context effect and the associated P values are reported for each topsoil health indicator. Where Glastir bundles were not reprehensively covered in our dataset, these were not analysed and are greyed out in the table.

		Arable Management		Habitat Management		Woodland Management		Grazing Low/No Input Management		Context: Historic AES	
Habitat	Indicator	Glastir effect	P value	Glastir effect	P value	Glastir effect	P value	Glastir effect	P value	historic AES effect	P value
Broadleaved Mixed and Yew Woodland	Carbon (g/kg, from organic matter)					41.0	0.010			-28.6	0.050
	pH in water					-0.23	0.430			0.10	0.630
	N (g/100g dry soil)					0.12	0.140			-0.10	0.350
	Carbon density (tC/ha)					12.7	0.220			-0.4	0.960
	Bulk density (g/cm3)					-0.19	0.130			0.13	0.050

4.1.2.1 Topsoil Carbon Concentration

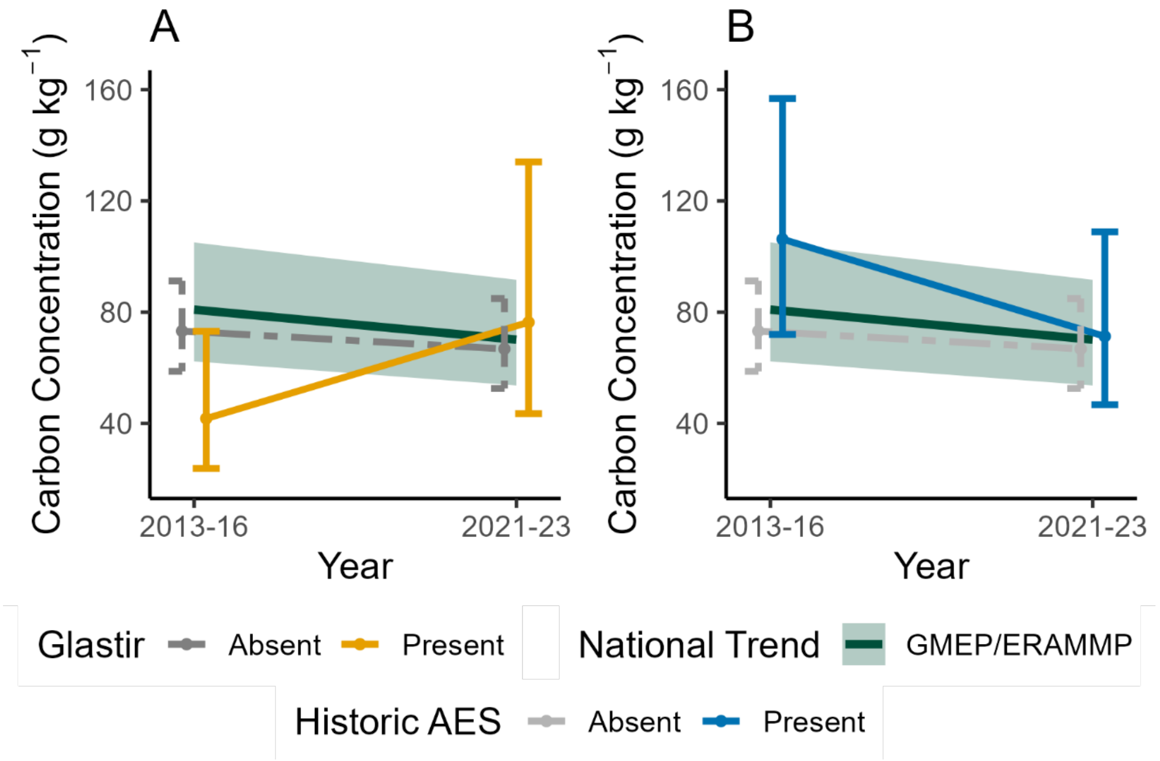

Figure 4-2 Trend in topsoil carbon concentration between 2013-16 and 2021-23 in Broadleaved Mixed and Yew Woodland showing both national trends and effect of specific Glastir Option Bundle A) Glastir Woodland management, and B) historic AES.

4.1.2.2 Topsoil pH in Water

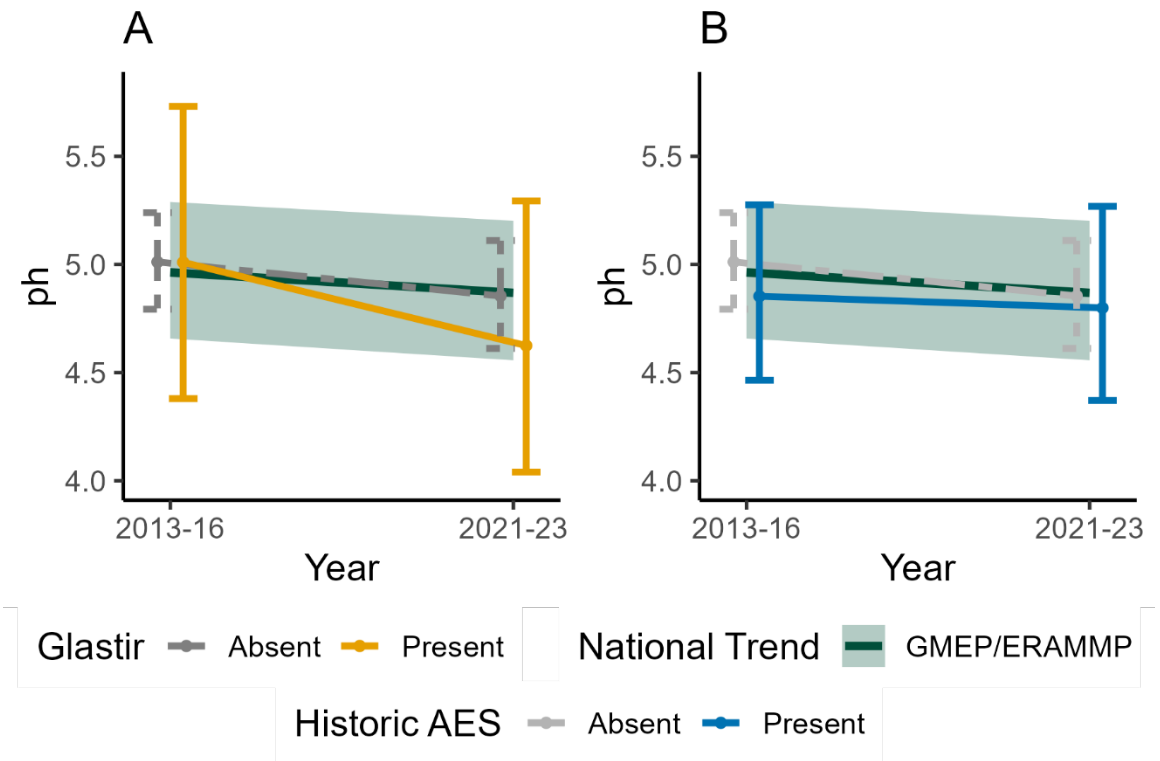

Figure 4-3 Trend in topsoil pH between 2013-16 and 2021-23 in Broadleaved Mixed and Yew Woodland showing both national trends and effect of specific Glastir Option Bundle A) Glastir Woodland management, and B) historic AES.

4.1.2.3 Topsoil Nitrogen Concentration

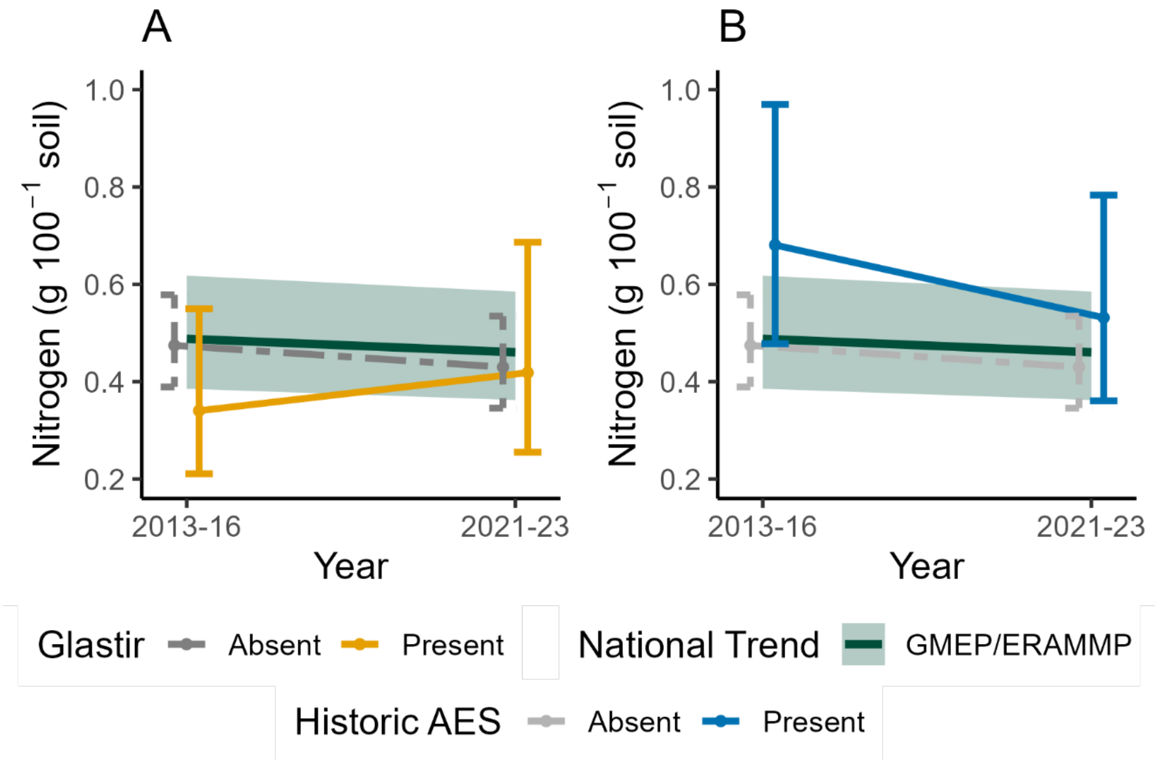

Figure 4-4 Trend in topsoil nitrogen concentration between 2013-16 and 2021-23 in Broadleaved Mixed and Yew Woodland showing both national trends and effect of specific Glastir Option Bundle A) Glastir Woodland management, and B) historic AES.

4.1.2.4 Topsoil Carbon Density

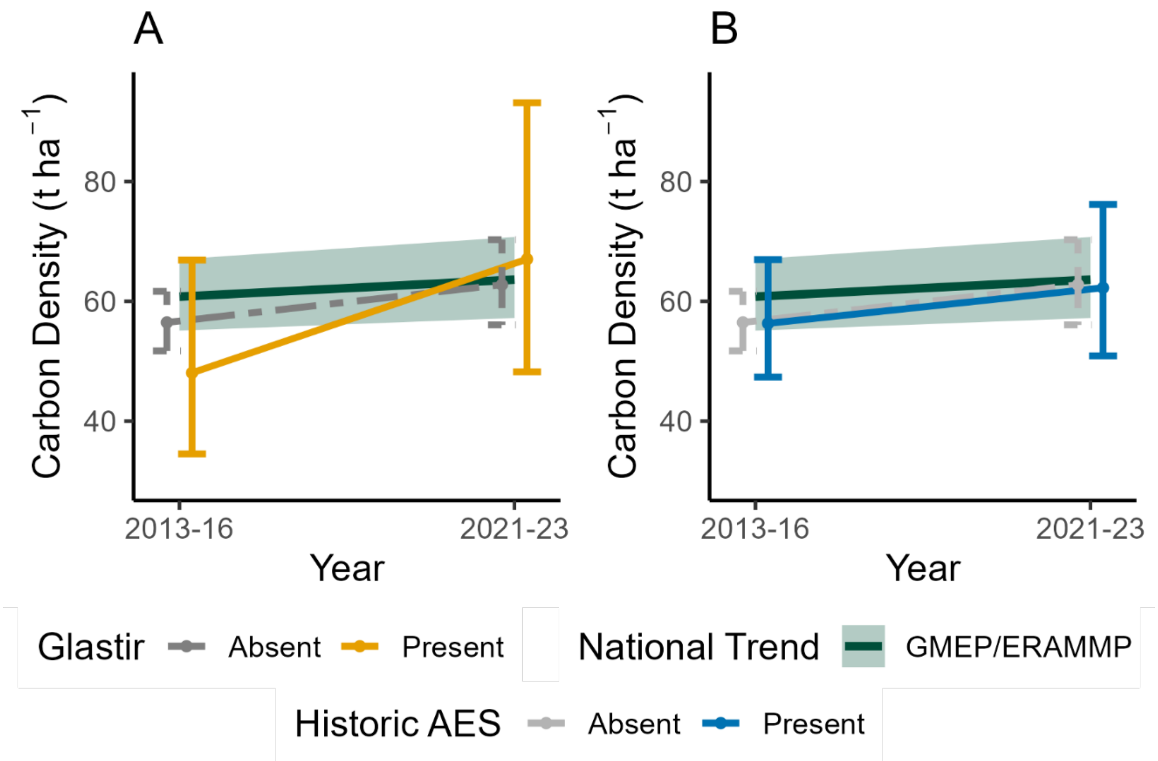

Figure 4-5 Trend in topsoil carbon density between 2013-16 and 2021-23 in Broadleaved Mixed and Yew Woodland showing both national trends and effect of specific Glastir Option Bundle A) Glastir Woodland management, and B) historic AES.

4.1.2.5 Topsoil Bulk Density

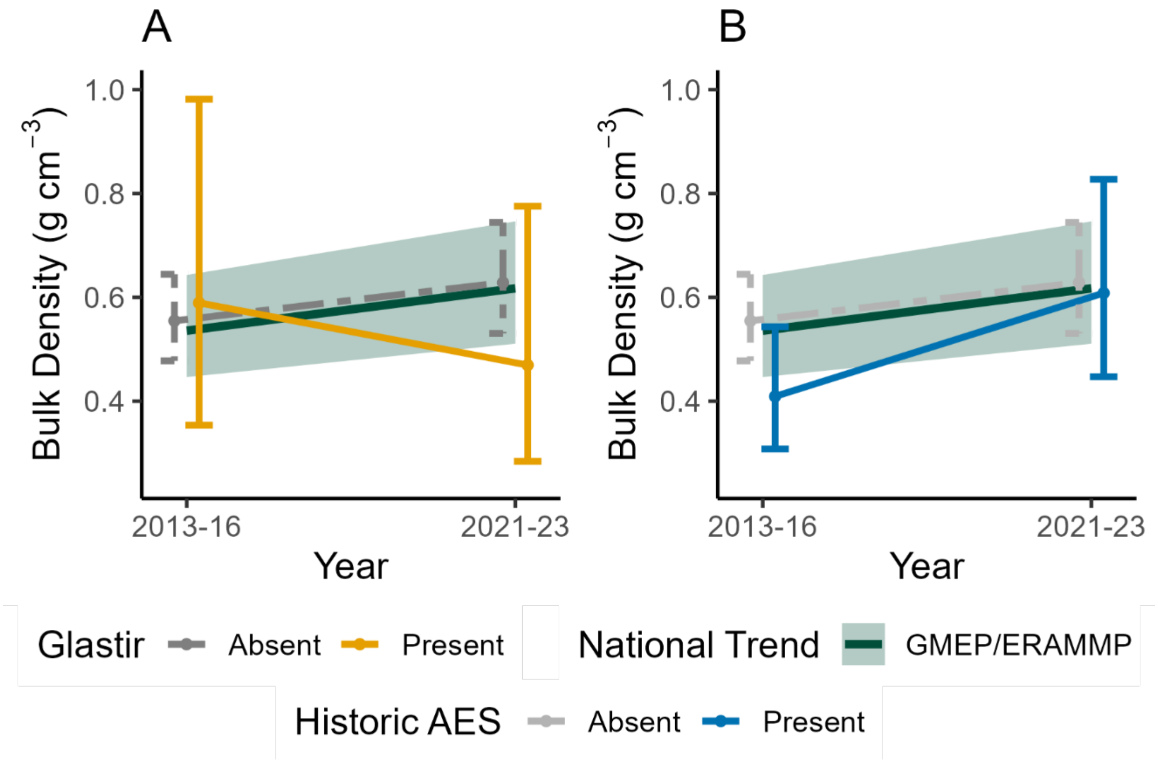

Figure 4-6 Trend in topsoil bulk density between 2013-16 and 2021-23 in Broadleaved Mixed and Yew Woodland showing both national trends and effect of specific Glastir Option Bundle A) Glastir Woodland management, and B) historic AES.

4.2 Coniferous Woodland

4.2.1 National Trend

Table 4-4 Long-term and short-term trends in topsoil indicators for Coniferous Woodland. Long-term data and trends in indicators for Coniferous Woodland were extracted from Emmett et al. 2010 using the Countryside survey for Wales 1978 to 2007. Data analysis from this report cover the time periods 2013-16 (GMEP) and 2021-23 (ERAMMP). Models were run for each soil health indicator and Mean values, minimum and maximum confidence intervals (CI) were extracted and the mean change estimated. The p-value for the mean change in each soil health indicator is reported. No data are shown as grey boxes.

			Countryside survey				Trend 1978/98-2007		2013-16			2021-23			Trend 2016-2022	
Asset class	Habitat	Indicator	1978	1990	1998	2007	Mean change	P value	Mean	min CI	max CI	Mean	min CI	max CI	Mean change	P value
Woodland	Coniferous Woodland	Carbon (g/kg, from organic matter)	176.6		233.6	184.3	7.7	<0.05	146.9	108.2	199.3	134.6	99.4	182.4	-12.2	0.146
		pH in water	3.73		4.22	4.14	0.41	>0.05	4.21	4.07	4.36	4.25	4.10	4.40	0.03	0.583
		N (g/100g dry soil)							0.69	0.50	0.95	0.65	0.47	0.90	-0.04	0.464
		Carbon density (tC/ha)	65.7		94.0	76.2	10.5	>0.05	60.6	54.4	67.4	69.7	62.6	77.6	9.2	0.001
		Bulk density (g/cm3)							0.34	0.25	0.46	0.45	0.33	0.62	0.11	0.000

4.2.2 Glastir Analysis

For Coniferous Woodland, soil data did not sufficiently intersect with Glastir actions / bundles as shown below. Thus, no Glastir analysis on topsoil indicators was performed for Coniferous Woodland.

Table 4-5 Data coverage for the Glastir analysis for Coniferous Woodland. The Glastir Woodland management bundle, and presence in historic AES schemes were represented in the data, but with very low coverage only. Glastir bundle or historic AES present (0 = no, 1 = yes), and count for combinations for each time point (2013-16 and 2021-23).

SURVEY	Woodland management	Context: Historic AES	Count
2013-16	0	0	71
2013-16	0	1	2
2013-16	1	0	1
2021-23	0	0	51
2021-23	1	0	1

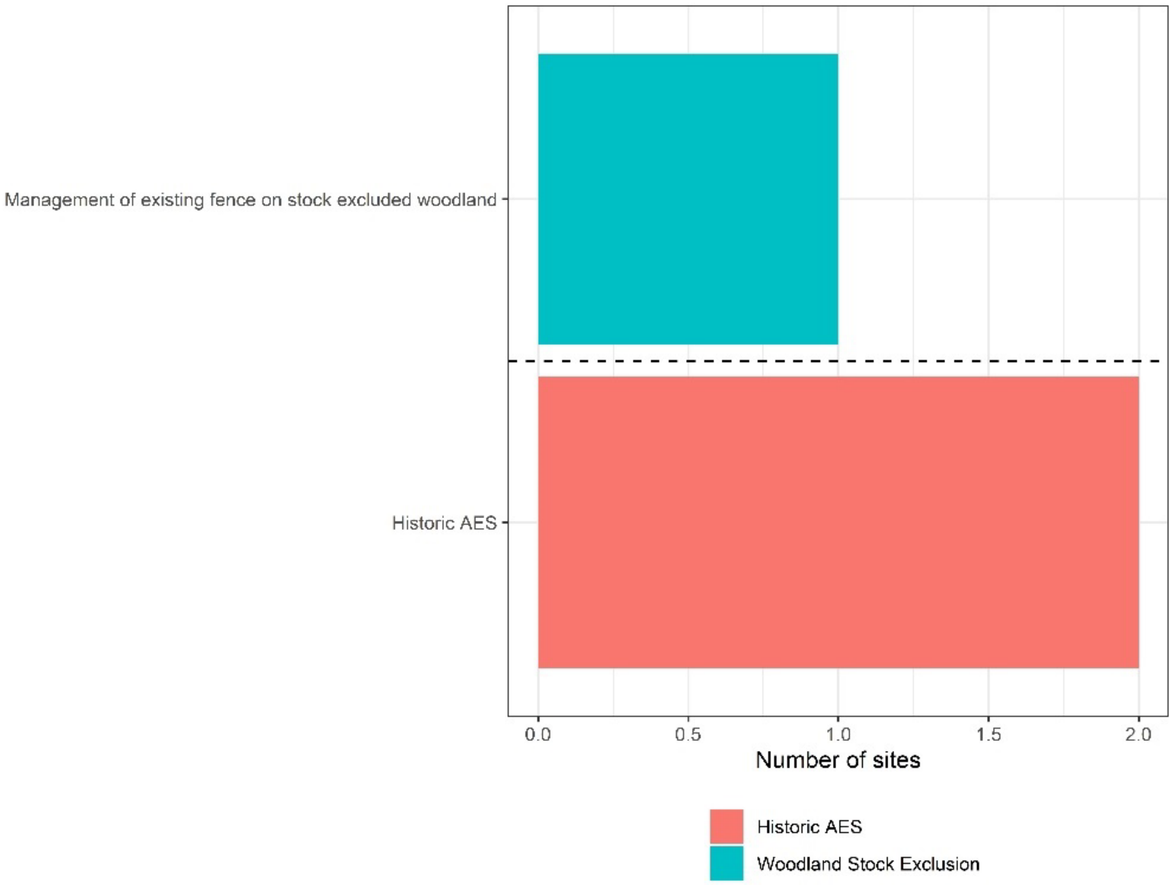

Figure 4-7 Action frequency in Glastir bundles present in Coniferous Woodland for resurveyed sites. Neither the Woodland stock exclusion management action, nor presence in historic AES was sufficiently represented to be analysed for Coniferous Woodland.

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4.3 Dwarf Shrub Heath

4.3.1 National Trend

Table 4-6 Long-term and short-term trends in topsoil indicators for Dwarf Shrub Heath. Long-term data and trends in indicators for Dwarf Shrub Heath were extracted from Emmett et al. 2010 using the Countryside survey for Wales 1978 to 2007. Data analysis from this report cover the time periods 2013-16 (GMEP) and 2021-23 (ERAMMP). Models were run for each soil health indicator and Mean values, minimum and maximum confidence intervals (CI) were extracted and the mean change estimated. The p-value for the mean change in each soil health indicator is reported. No data are shown as grey boxes.

			Countryside survey				Trend 1978/98-2007		2013-16			2021-23			Trend 2016-2022	
Asset class	Habitat	Indicator	1978	1990	1998	2007	Mean change	P value	Mean	min CI	max CI	Mean	min CI	max CI	Mean change	P value
MMH	Dwarf Shrub Heath	Carbon (g/kg, from organic matter)	210.7		267.2	280.0	69.3	>0.05	178.4	127.8	249.2	177.5	128.0	246.3	-0.9	0.956
		pH in water	4.13		4.53	4.40	0.27	>0.05	4.47	4.26	4.68	4.20	4.02	4.38	-0.27	0.004
		N (g/100g dry soil)							1.01	0.76	1.35	1.01	0.77	1.33	0.00	0.984
		Carbon density (tC/ha)	134.1		106.8	103.3	-30.8	<0.05	76.1	64.3	89.9	83.0	70.8	97.3	6.9	0.093
		Bulk density (g/cm3)							0.34	0.27	0.44	0.38	0.29	0.48	0.03	0.192

4.3.2 Glastir Analysis

Glastir impact on Dwarf Shrub Heath topsoil indicators was tested using the Habitat Management bundle, Organics and Commons bundles, and presence in historic AES. The Habitat management bundle was dominated by actions on “Additional Management Payment – Reduced stocking” and “Grazing management of open country”. The Organics bundle contained the action on “Glastir Organics Interventions”, and the Commons bundle was covered by the action “Commons management of options combined”.

The Organics bundle had lower than ten repeated measurements represented in the dataset; the presence in historic AES had lower than 5 re-visited plots in the dataset. The Grazing Inputs management was not sufficiently represented in the Dwarf Shrub Heath dataset for soils to be analysed for its effects on topsoil health indicators.

Table 4-7 Data coverage for the Glastir analysis for Dwarf Shrub Heath. The Glastir Habitat management bundle, Organics and Commons bundles, and presence in historic AES schemes were analysed. Glastir bundle or historic AES present (0 = no, 1 = yes), and count for combinations for each time point (2013-16 and 2021-23).

SURVEY	Habitat Management	B_Organics	B_Commons	Context: Historic AES	Count
2013-16	0	0	0	0	23
013-16	0	0	0	1	9
013-16	0	0	1	0	9
013-16	0	0	1	1	2
013-16	1	0	0	0	4
013-16	1	0	0	1	27
013-16	1	0	1	0	8
2013-16	1	1	0	0	2
2013-16	1	1	0	1	8
2021-23	0	0	0	0	8
2021-23	0	0	0	1	5
2021-23	0	0	1	0	9
2021-23	0	0	1	1	2
2021-23	1	0	0	0	3
2021-23	1	0	0	1	10
2021-23	1	0	1	0	4
2021-23	1	1	0	0	2
2021-23	1	1	0	1	6

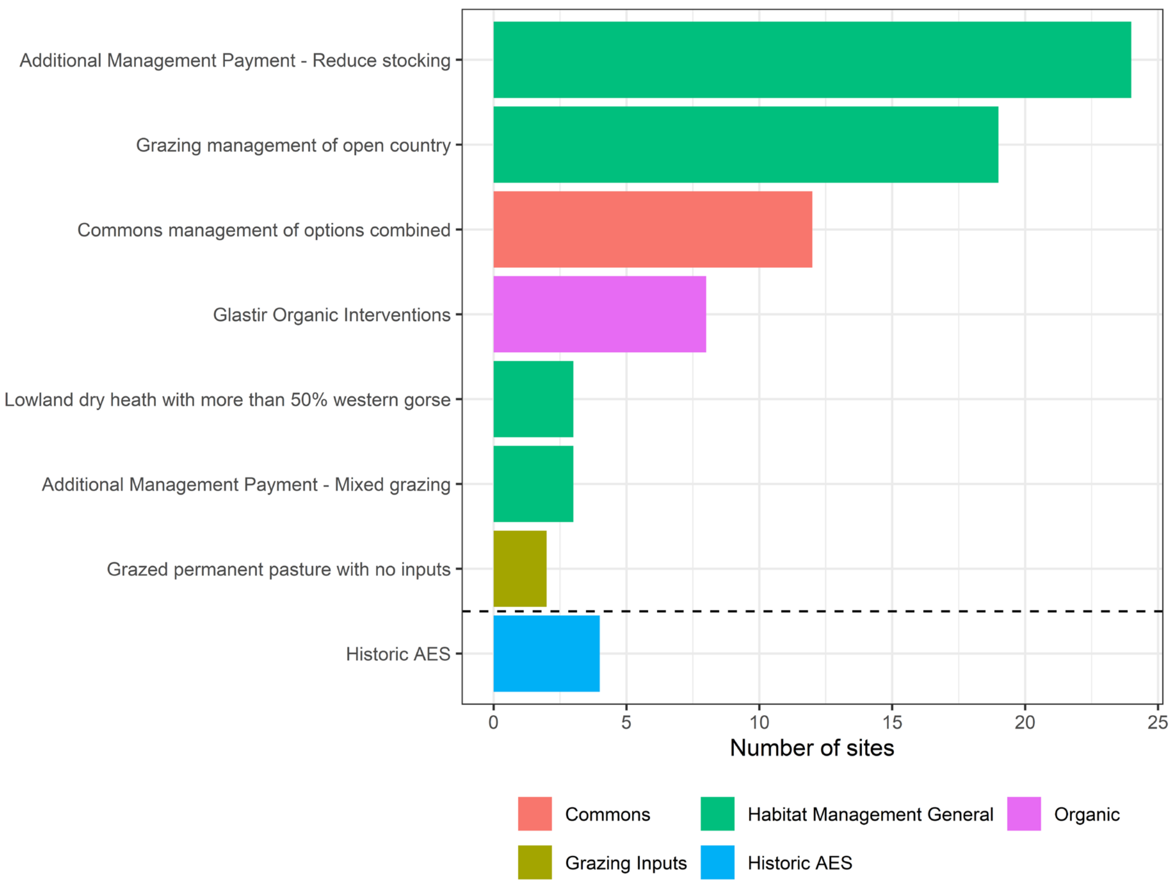

Figure 4-8 Action frequency in Glastir bundles present in Dwarf Shrub Heath for direct plot repeats. The Glastir Grazing inputs management bundle (Action Grazed permanent pasture with no inputs only) was not analysed due to low representation in the dataset.

Table 4-8 Glastir analysis for topsoil health indicators in Dwarf Shrub Heath. The models test for the effect of Glastir bundle compared to plots without the Glastir bundle on topsoil health indicators. Context effect was tested using information related to participation in historic agri-environment schemes (AES). The Glastir and Context effect was tested for 2013-16 (GMEP) compared to 2021-23 (ERAMMP). The Glastir bundle/Context effect and the associated P values are reported for each topsoil health indicator.

		Habitat Management		Organics		Commons		Context: Historic AES	
Habitat	**Indicator**	Glastir effect	P value	Glastir effect	P value	Glastir effect	P value	Historic AES effect	P value
Dwarf Shrub Heath	**Carbon (g/kg, from organic matter)**	20.47	0.400	53.48	0.280	46.31	0.280	20.4	0.560
	pH in water	0.01	0.960	-0.16	0.350	-0.01	0.900	0.09	0.510
	N (g/100g dry soil)	-0.07	0.660	0.42	0.050	0.12	0.430	0.03	0.730
	Carbon density (tC/ha)	-16.13	0.030	24.81	0.020	0.4	0.960	9.16	0.230
	Bulk density (g/cm3)	0.0	0.850	-0.09	0.360	-0.07	0.290	-0.07	0.320

4.3.2.1 Topsoil Carbon Concentration

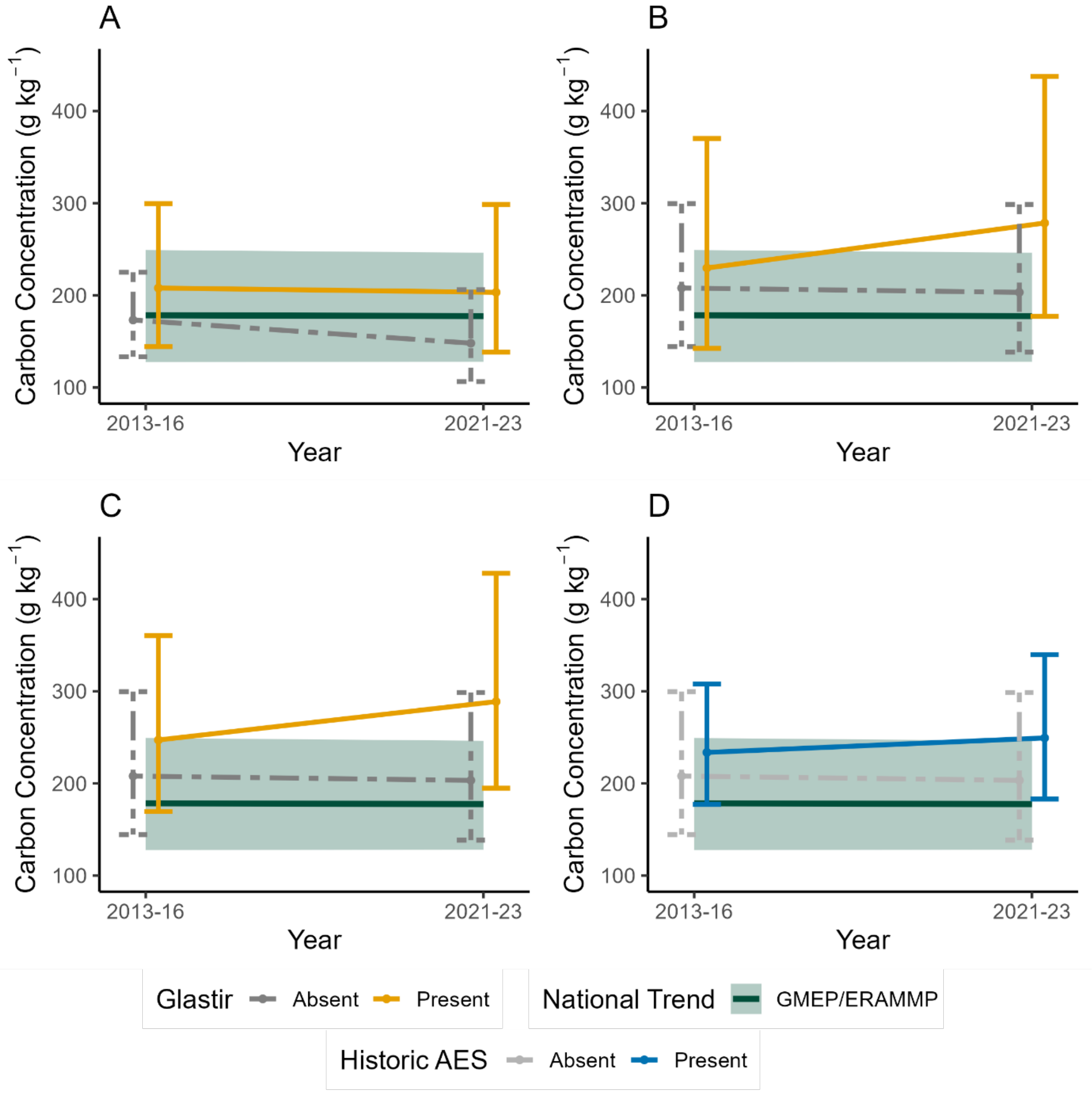

Figure 4-9 Trend in topsoil carbon concentration between 2013-16 and 2021-23 in Dwarf Shrub Heath showing both national trend and effect of the A) Glastir Habitat Management bundle, B) Organics bundle, C) Commons bundle, and D) presence in historic agri-environment schemes (AES)

4.3.2.2 Topsoil pH in Water

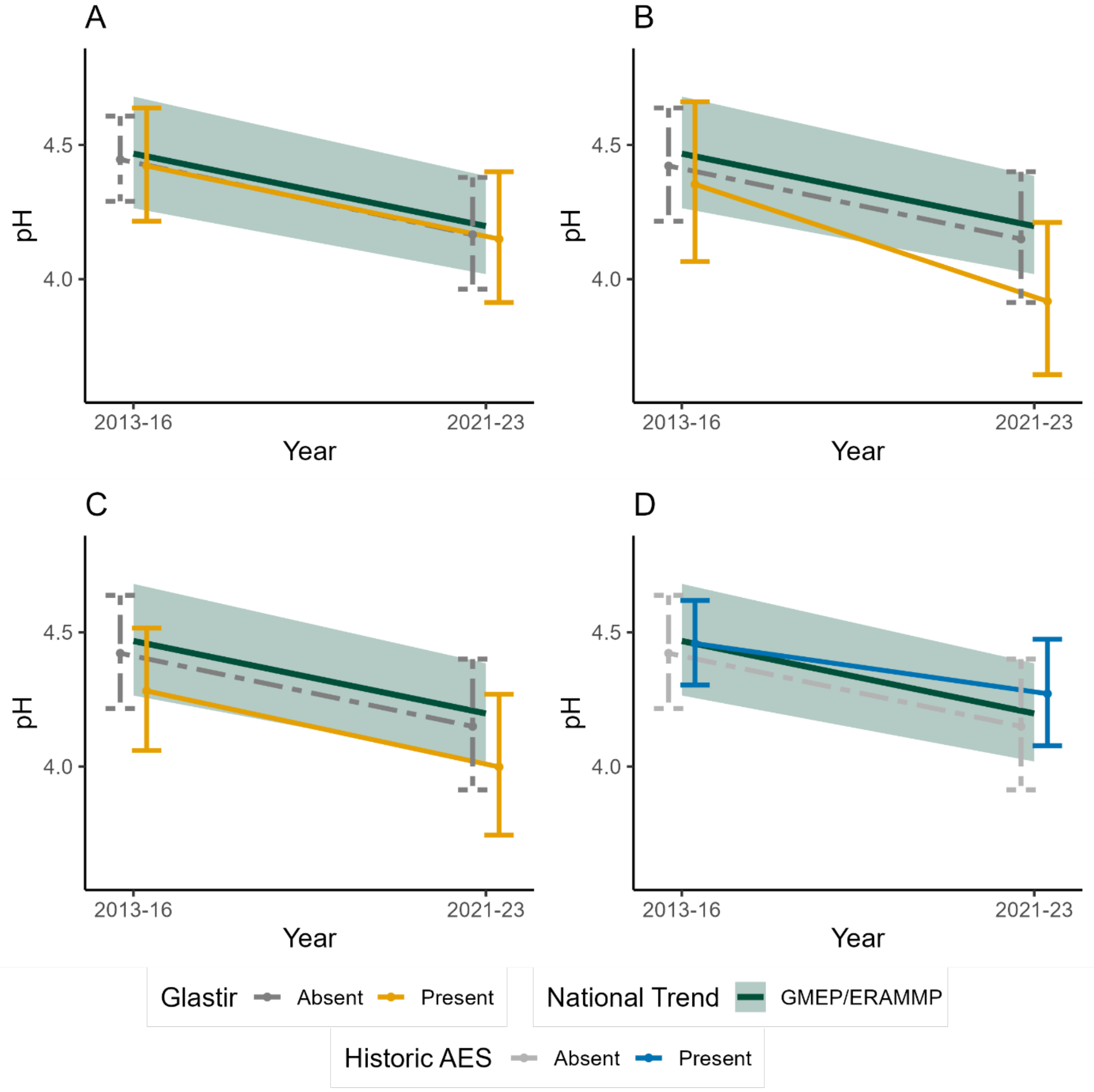

Figure 4-10 Trend in topsoil pH between 2013-16 and 2021-23 in Dwarf Shrub Heath showing both national trend and effect of A) Glastir Habitat Management bundle, B) Organics bundle, C) Commons bundle, and D) presence in historic agri-environment schemes (AES)

4.3.2.3 Topsoil Nitrogen Concentration

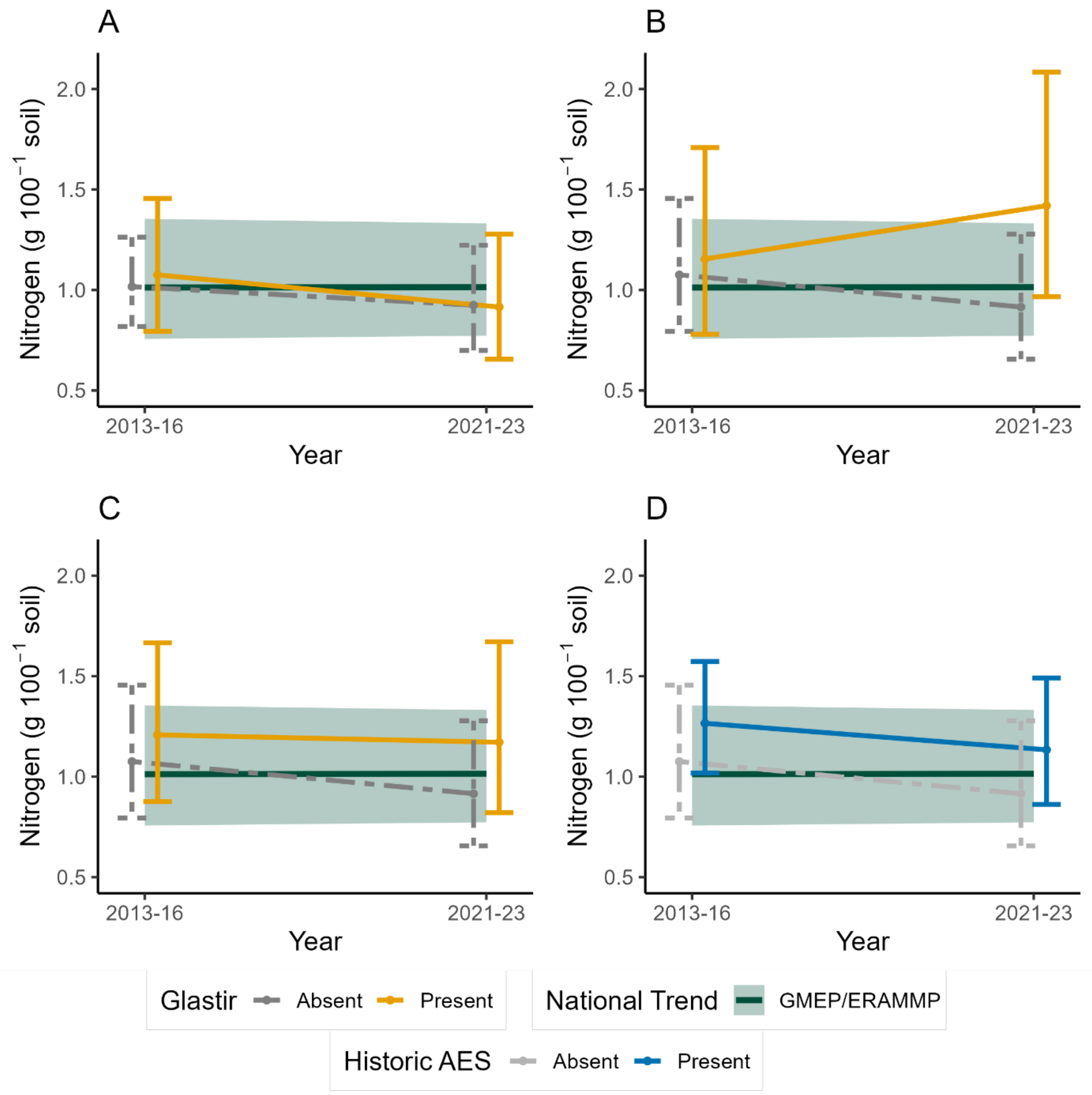

Figure 4-11 Trend in topsoil nitrogen concentration between 2013-16 and 2021-23 in Dwarf Shrub Heath showing both national trend and effect of the A) Glastir Habitat Management bundle, B) Organics bundle, C) Commons bundle, and D) presence in historic agri-environment schemes (AES)

4.3.2.4 Topsoil Carbon Density

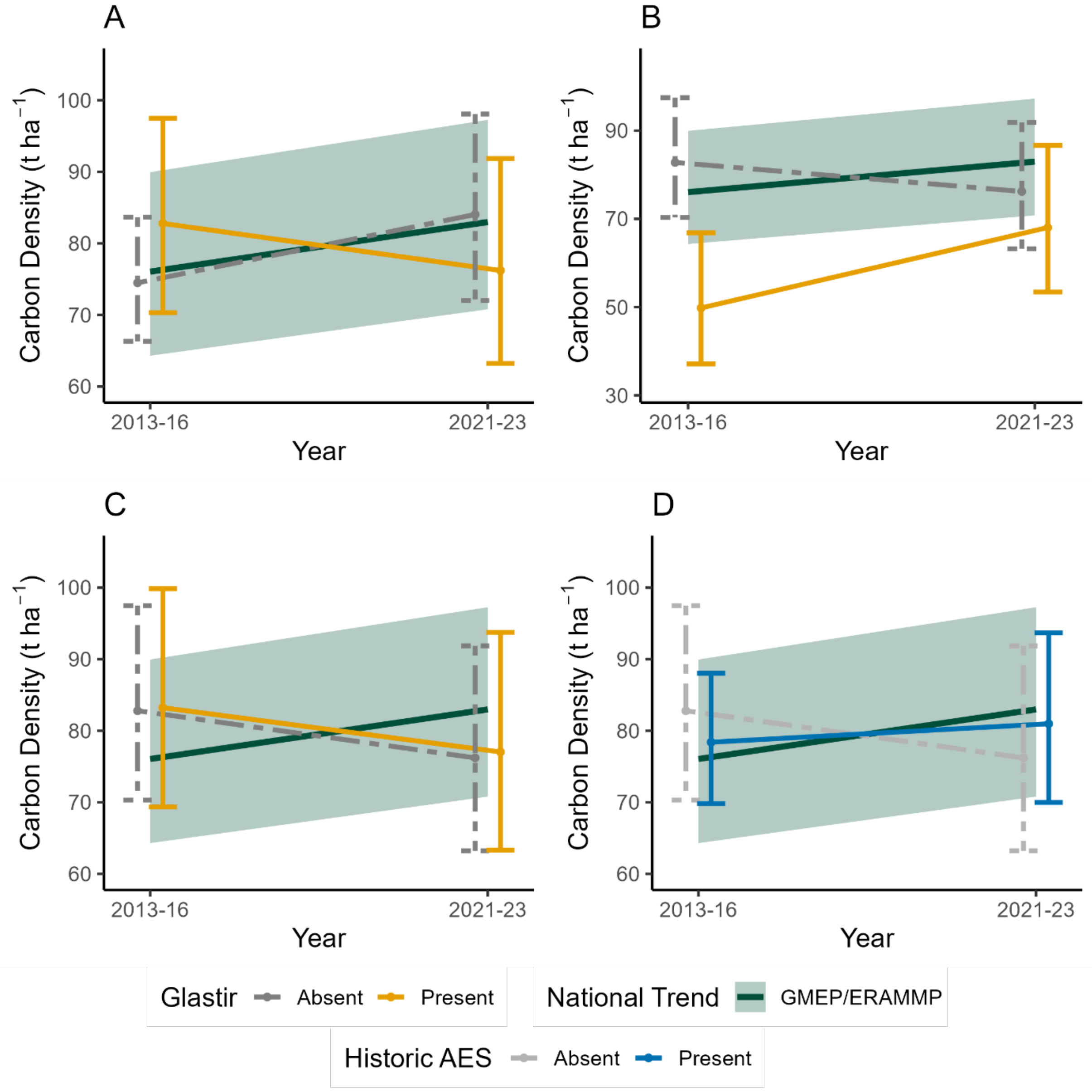

Figure 4-12 Trend in topsoil carbon density between 2013-16 and 2021-23 in Dwarf Shrub Heath showing both national trend and effect of the A) Glastir Habitat Management bundle, B) Organics bundle, C) Commons bundle, and D) presence in historic agri-environment schemes (AES)

4.3.2.5 Topsoil Bulk Density

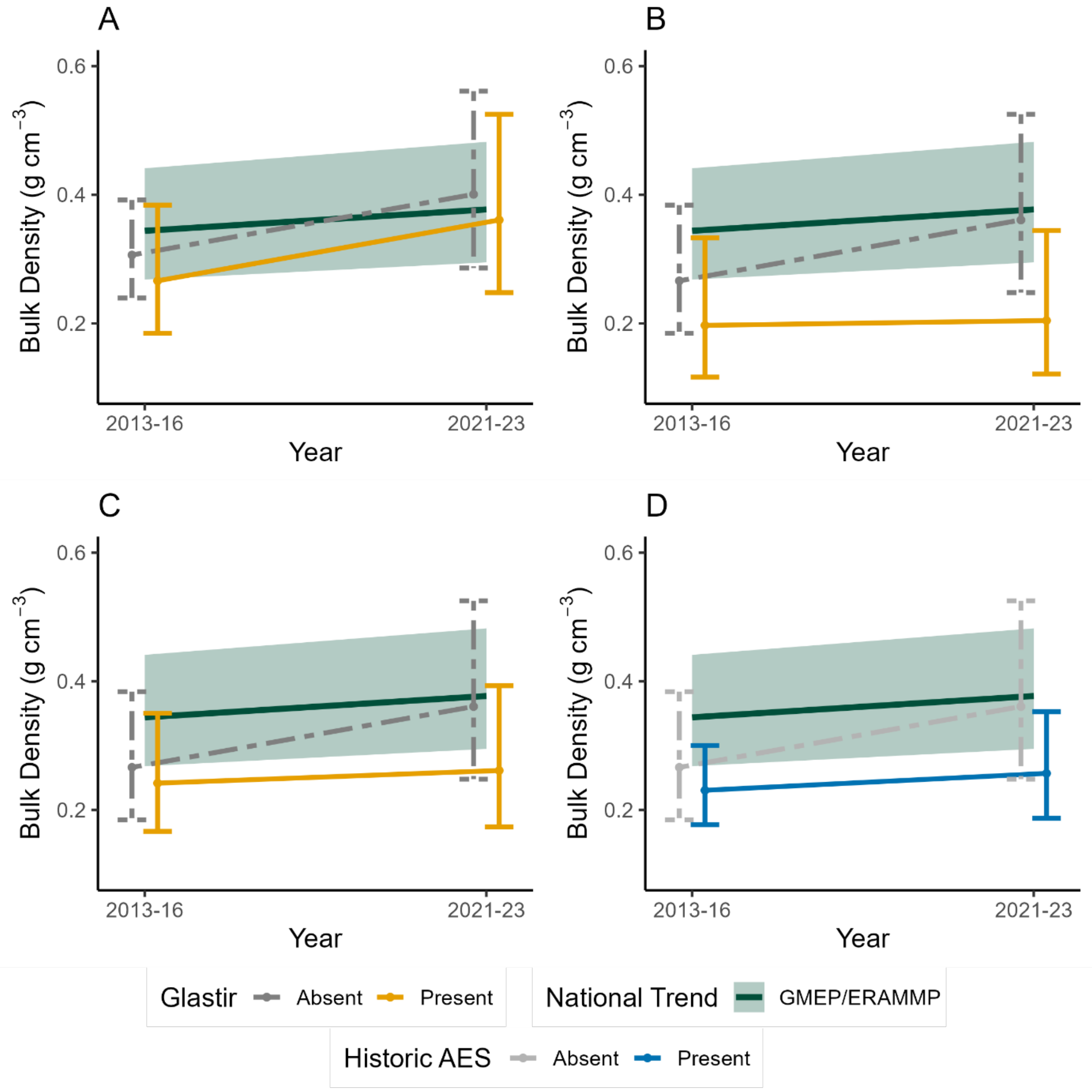

Figure 4-13 Trend in topsoil bulk density between 2013-16 and 2021-23 in Dwarf Shrub Heath showing both national trend and effect of the A) Glastir Habitat Management bundle, B) Organics bundle, C) Commons bundle, and D) presence in historic agri-environment schemes (AES)

4.4 Bog

4.4.1 National Trend

Table 4-9 Long-term and short-term trends in topsoil indicators for Bog. Long-term data and trends in indicators for was not available from Emmett et al. 2010 using the Countryside survey for Wales 1978 to 2007. Data analysis from this report cover the time periods 2013-16 (GMEP) and 2021-23 (ERAMMP). Models were run for each soil health indicator and Mean values, minimum and maximum confidence intervals (CI) were extracted and the mean change estimated. The p-value for the mean change in each soil health indicator is reported. No data are shown as grey boxes.

			Countryside survey				Trend 1978-90-2007		2013-16			2021-23			Trend 2016-2022	
Asset class	Habitat	Indicator	1978	1990	1998	2007	Mean change	P value	Mean	min CI	max CI	Mean	min CI	max CI	Mean change	P value
MMH	Bog	Carbon (g/kg, from organic matter)							343.0	264.9	444.1	364.2	262.3	505.7	21.2	0.662
		pH in water							4.27	4.06	4.48	4.03	3.83	4.24	-0.24	0.000
		N (g/100g dry soil)							1.53	1.16	2.01	1.78	1.26	2.53	0.26	0.329
		Carbon density (tC/ha)							66.3	55.9	78.7	73.2	61.9	86.6	6.9	0.204
		Bulk density (g/cm3)							0.15	0.10	0.22	0.15	0.10	0.23	0.01	0.848

4.4.2 Glastir Analysis

The Glastir effect on Bog topsoil indicators was assessed using the Habitat Management bundle, Organics and Commons bundles. The impact of presence in historic AES schemes on soil health indicators was assessed too, although the representation of data in the soils dataset for re-surveyed plots was below 5 between surveys.

The Habitat Management bundle was dominantly composed of the actions on Reduced stocking and Grazing management of the open country. The Organics bundle was represented by the action on "Glastir Organic Interventions", and the Commons bundle was represented by the action on "Commons management of options combined". The woodland management bundle was picked up, but the representation in the dataset was too low to be analysed for its effect on topsoil indicators.

Table 4-10 Data coverage available for the Glastir analysis for Bog. The Glastir Habitat Management bundle, Organics and Commons bundle, and presence in historic AES were analysed for topsoil health indicators in Bog. (0 = no, 1 = yes), and count for combinations for each time point (2013-16 and 2021-23).

National Trend	Habitat Management	Organics	Commons	Context: Historic AES	Count
2013-16	0	0	0	0	27
2013-16	0	0	0	1	9
2013-16	0	0	1	0	6
2013-16	1	0	0	0	6
2013-16	1	0	0	1	23
2013-16	1	0	1	0	9
2013-16	1	1	0	1	11
2021-23	0	0	0	0	12
2021-23	0	0	0	1	3
2021-23	0	0	1	0	5
2021-23	0	0	1	1	1
2021-23	1	0	0	0	4
2021-23	1	0	0	1	16
2021-23	1	0	1	0	3
2021-23	1	1	0	0	3
2021-23	1	1	0	1	4

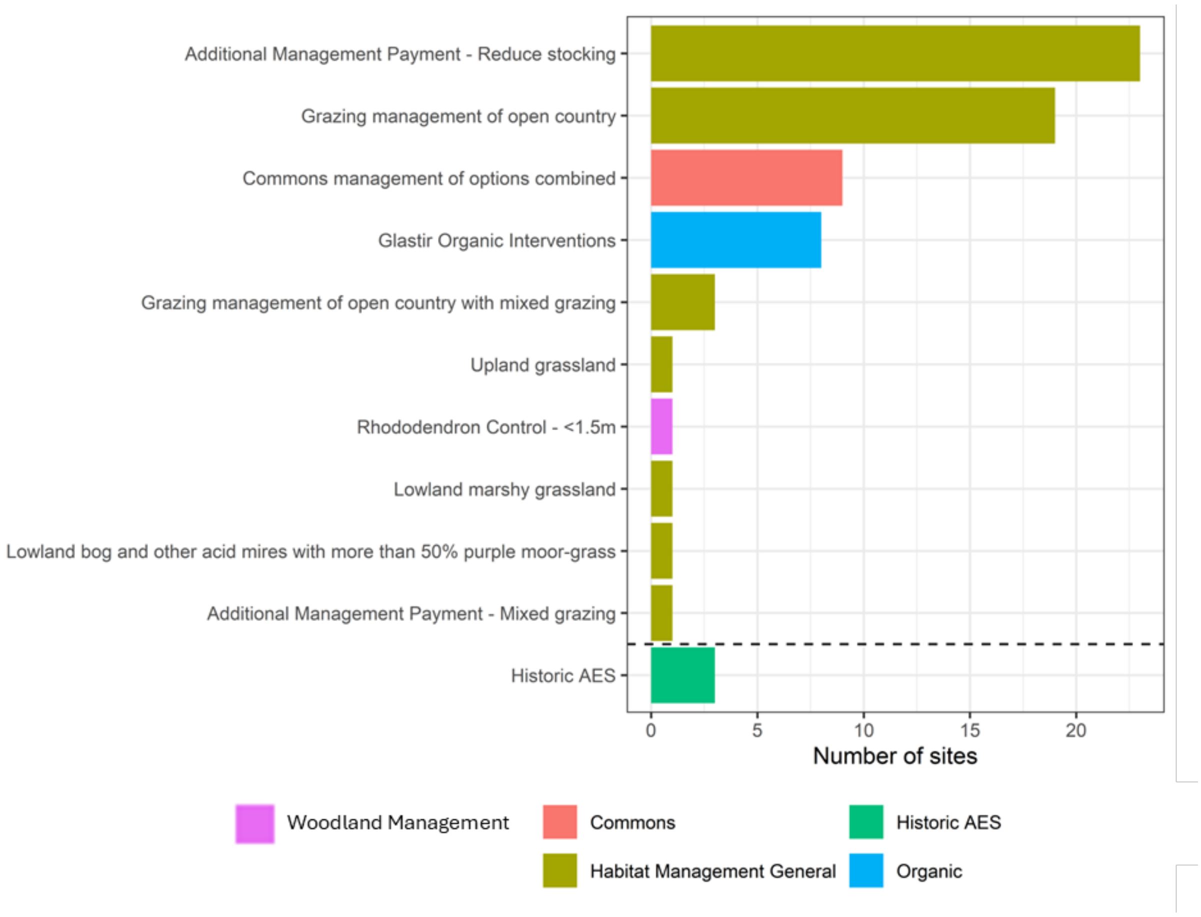

Figure 4-14 Action frequency in Glastir bundles present in Bog in re-surveyed plots. The woodland management bundle was not analysed due to very low representation in the dataset.

Table 4-11 Glastir analysis for topsoil health indicators in Bog. The models test for the effect of Glastir bundle compared to plots without the Glastir bundle on topsoil health indicators. Context effect was tested using information related to participation in historic agri-environment schemes (AES). The Glastir and Context effect was tested for 2013-16 (GMEP) compared to 2021-23 (ERAMMP). The Glastir bundle/Context effect and the associated P values are reported for each topsoil health indicator.

		Habitat Management		Organics		Commons		Context: Historic AES	
Habitat	Indicator	Glastir effect	P value	Glastir effect	P value	Glastir effect	P value	Historic AES effect	P value
Bog	Carbon (g/kg, from organic matter)	-9.81	0.710	6.96	0.850	-38.83	0.230	2.7	0.880
	pH in water	-0.24	0.020	0.03	0.750	0.01	0.750	0.11	0.190
	N (g/100g dry soil)	-0.06	0.590	0.05	0.700	-0.4	0.040	0.03	0.860
	Carbon density (tC/ha)	-0.79	0.710	-3.02	0.850	-10.37	0.440	-9.1	0.340
	Bulk density (g/cm3)	-0.02	0.350	-0.05	0.100	0.02	0.430	0.01	0.700

4.4.2.1 Topsoil Carbon Concentration

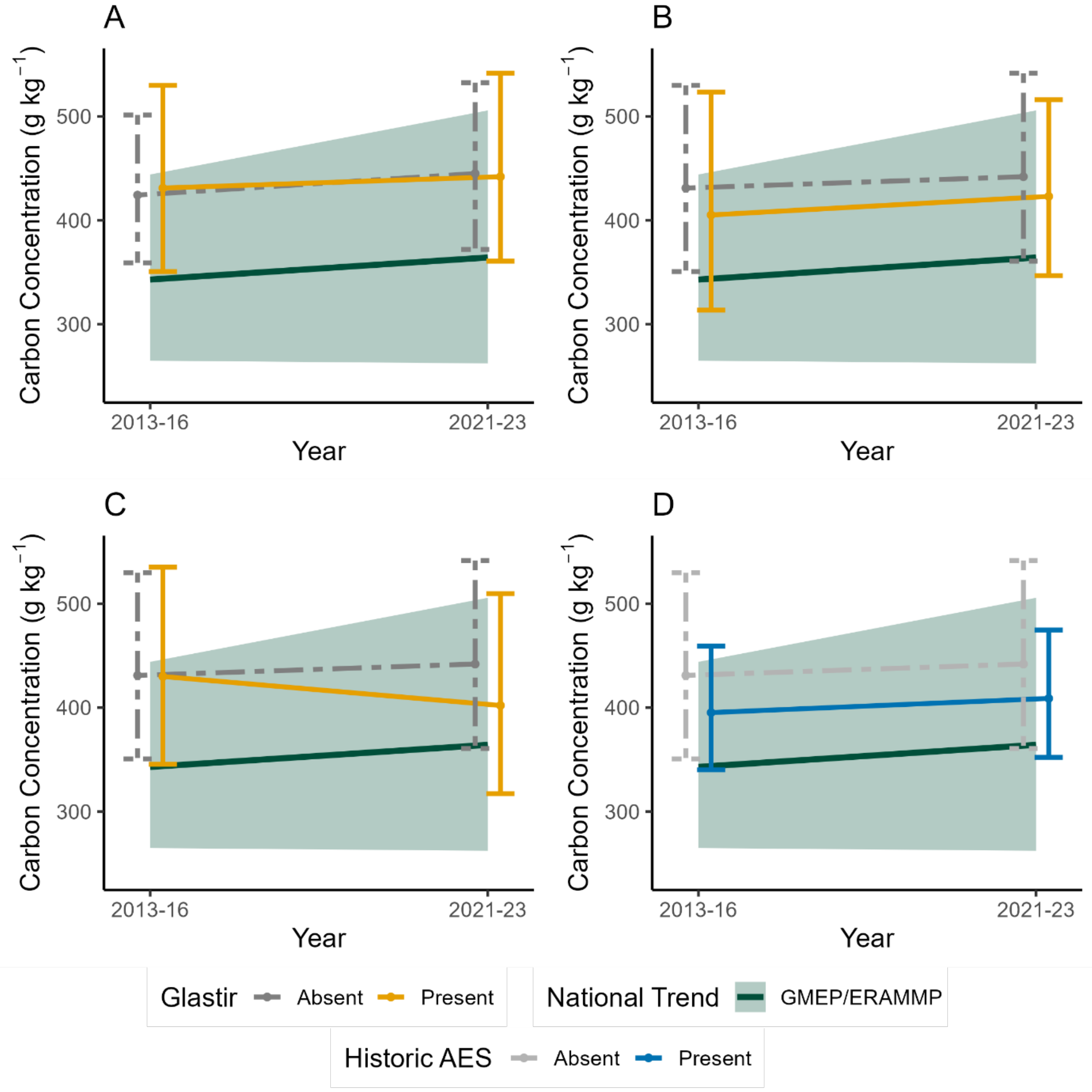

Figure 4-15 Trend in topsoil carbon concentration between 2013-16 and 2021-23 in Bog showing both national trends and effect of specific Glastir Option Bundle A) Glastir Habitat management, B) Organics bundle, C) Commons bundle, and D) presence in historic agri-environment schemes (AES).

4.4.2.2 Topsoil pH in Water

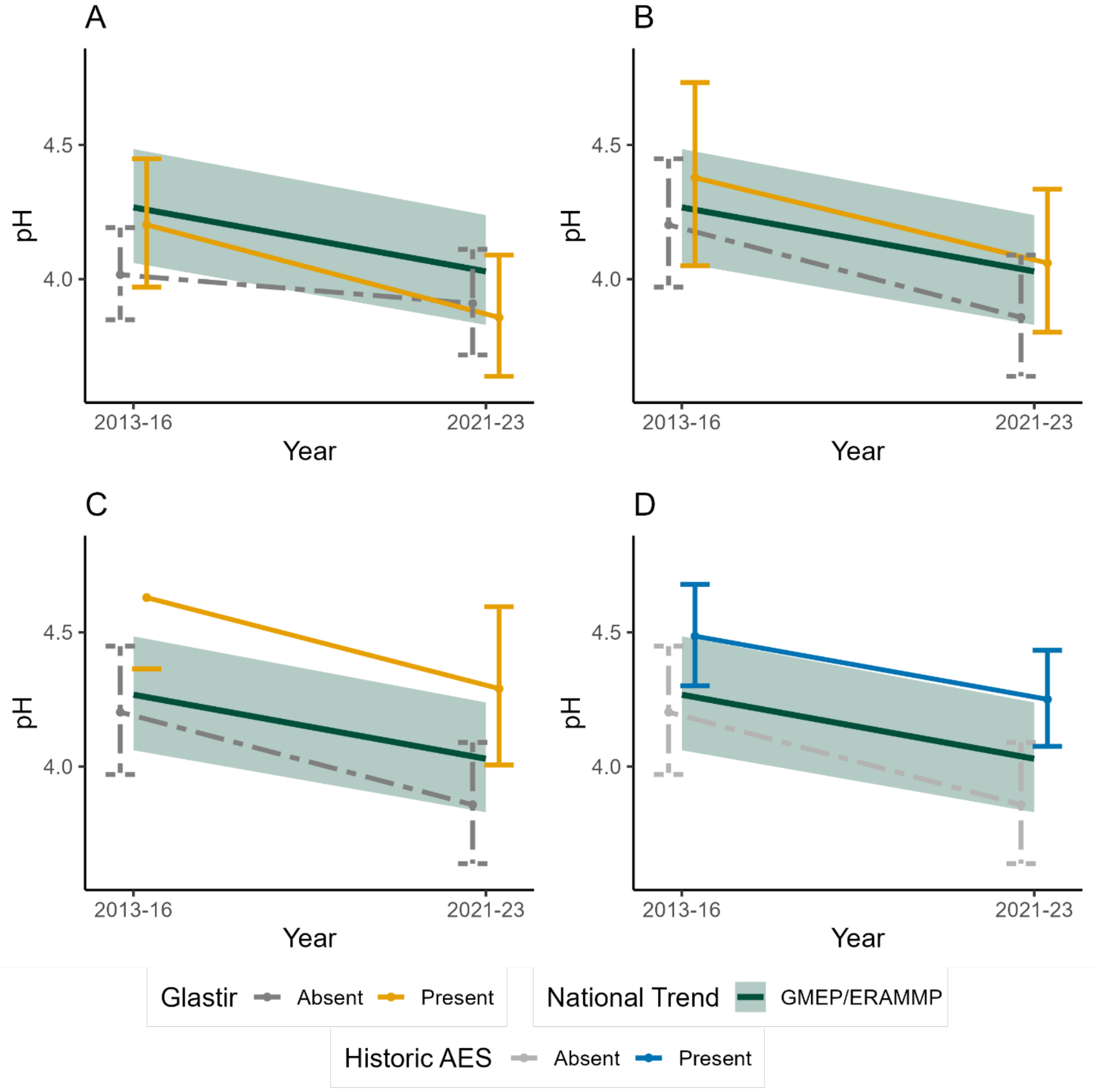

Figure 4-16 Trend in topsoil pH between 2013-16 and 2021-23 in Bog showing both national trends and effect of specific Glastir Option Bundle A) Glastir Habitat management, B) Organics bundle, C) Commons bundle, and D) presence in historic agri-environment schemes (AES).

4.4.2.3 Topsoil Nitrogen Concentration

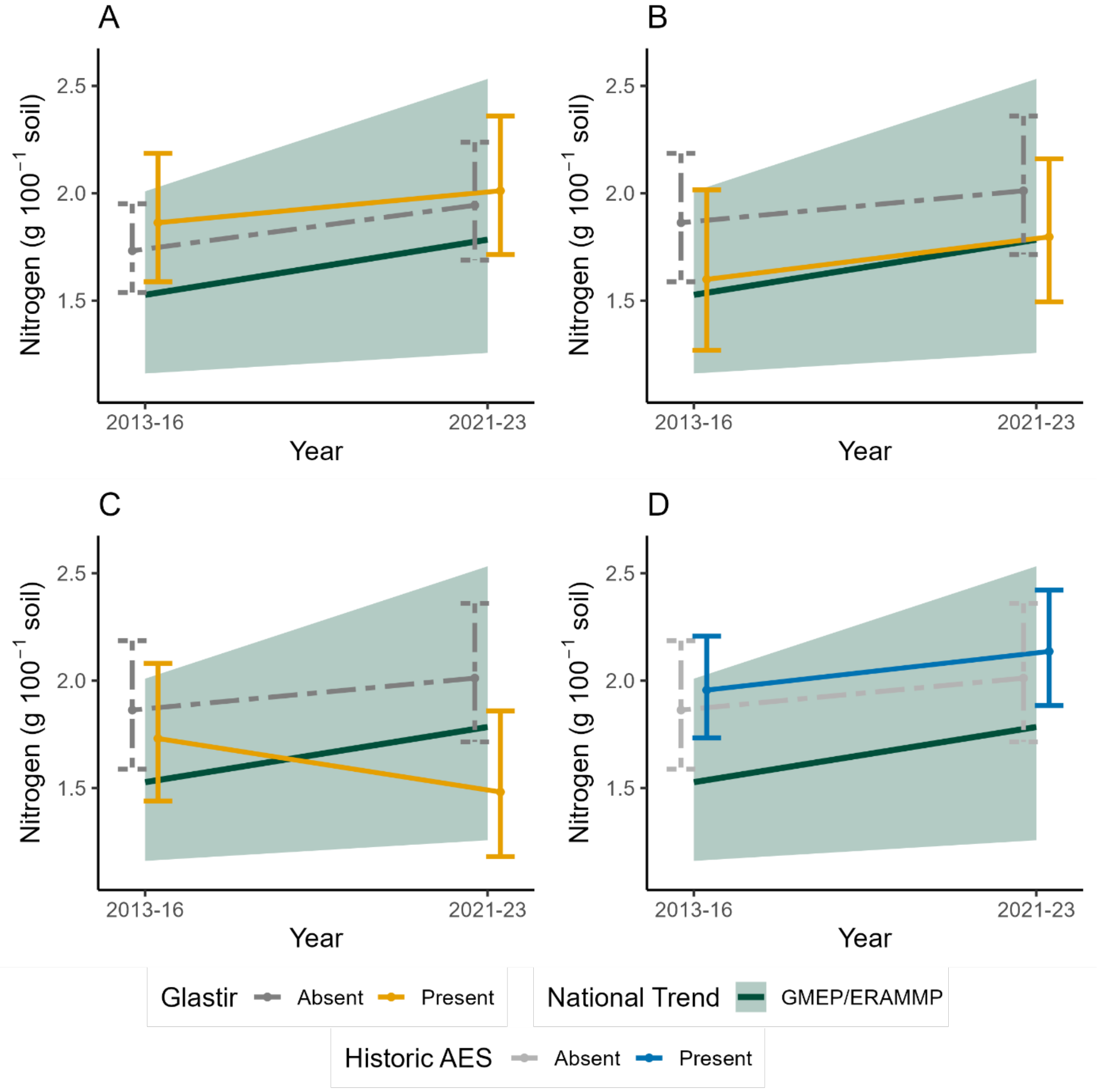

Figure 4-17 Trend in topsoil nitrogen concentration between 2013-16 and 2021-23 in Bog showing both national trends and effect of specific Glastir Option Bundle A) Glastir Habitat management, B) Organics bundle, C) Commons bundle, and D) presence in historic agri-environment schemes (AES).

4.4.2.4 Topsoil Carbon Density

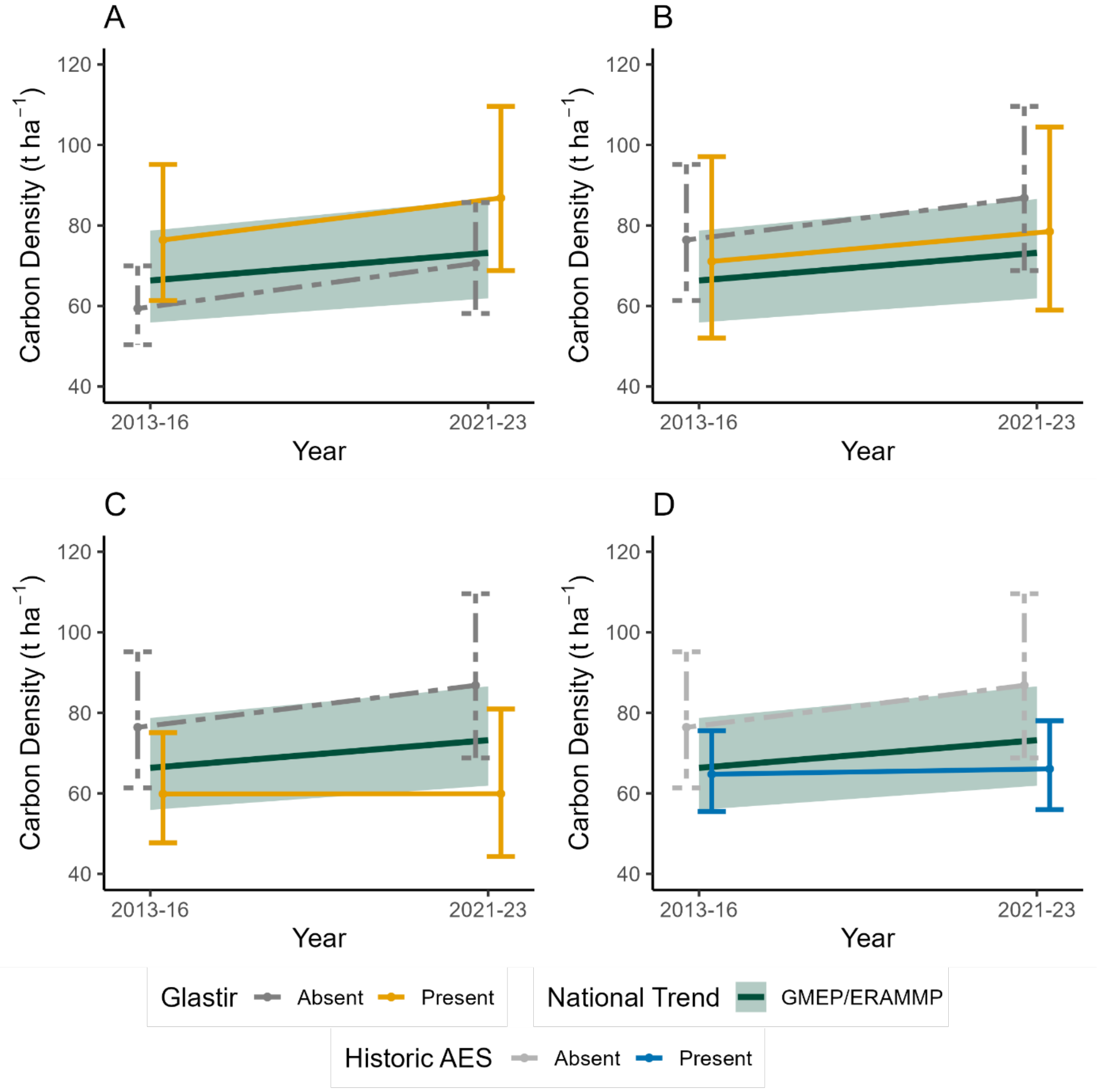

Figure 4-18 Trend in topsoil carbon density between 2013-16 and 2021-23 in Bog showing both national trends and effect of specific Glastir Option Bundle A) Glastir Habitat management, B) Organics bundle, C) Commons bundle, and D) presence in historic agri-environment schemes (AES).

4.4.2.5 Topsoil Bulk Density

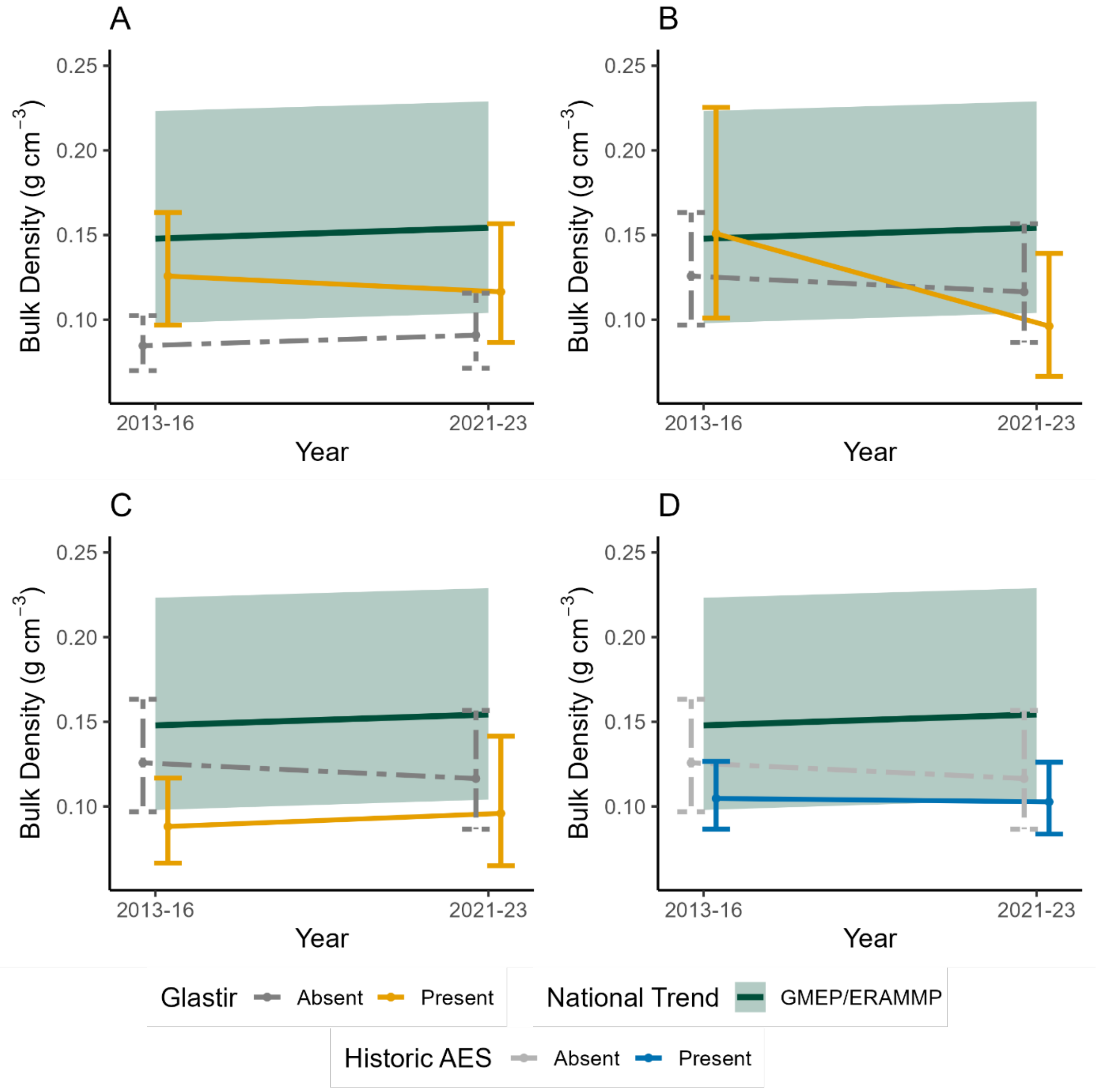

Figure 4-19 Trend in topsoil bulk density between 2013-16 and 2021-23 in Bog showing both national trends and effect of specific Glastir Option Bundle A) Glastir Habitat management, B) Organics bundle, C) Commons bundle, and D) presence in historic agri-environment schemes (AES).

4.5 Bracken

4.5.1 National Trend

Table 4-12 Long-term and short-term trends in topsoil indicators for Bracken. Long-term data and trends in indicators for Bracken were not available from Emmett et al. 2010 using the Countryside survey for Wales 1978 to 2007. Data analysis from this report cover the time periods 2013-16 (GMEP) and 2021-23 (ERAMMP). Models were run for each soil health indicator and Mean values, minimum and maximum confidence intervals (CI) were extracted and the mean change estimated. The p-value for the mean change in each soil health indicator is reported. No data are shown as grey boxes.

			Countryside survey				Trend 1978-90-2007		2013-16			2021-23			Trend 2016-2022	
Asset class	Habitat	Indicator	1978	1990	1998	2007	Mean change	P value	Mean	min CI	max CI	Mean	min CI	max CI	Mean change	P value
MMH	Bracken	Carbon (g/kg, from organic matter)							71.4	57.3	88.9	64.7	52.2	80.0	-6.7	0.144
		pH in water							4.74	4.53	4.96	4.74	4.54	4.96	0.01	0.954
		N (g/100g dry soil)							0.49	0.40	0.60	0.45	0.37	0.55	-0.04	0.135
		Carbon density (tC/ha)							56.9	51.7	62.5	58.9	53.8	64.5	2.0	0.365
		Bulk density (g/cm3)							0.55	0.46	0.65	0.63	0.54	0.74	0.08	0.009

4.5.2 Glastir Analysis

The Glastir effect on topsoil indicators in Bracken was assessed using the Habitat Management bundle, the GrazingLow/No-Input Management bundle, and the Commons bundle. Presence in historic AES schemes was assessed too. The Woodland management bundle and Organics bundle were represented in the dataset with less than five plots resurveyed and were not analysed.

The Commons bundle with the action on "Commons management options combined" and the Habitat Management bundle with the actions on Reduced stocking and Grazing management of open country were well represented within the soil dataset. The Grazing ~~Lo/No~~ Inputs Management bundle was associated with the actions on Grazed permanent pasture with no inputs and with low inputs and presence in historic AES schemes were less well represented in the dataset~~.~~

Table 4-13 Data coverage available for the Glastir analysis for Bracken. The Glastir Habitat Management, Glastir Grazing Input management, and Commons bundles were analysed for Glastir impacts on soils in Bracken. Presence of historic AES was also assessed for its impact. Glastir bundle or historic AES present (0 = no, 1 = yes), and count for combinations for each time point (2013-16 and 2021-23).

National Trend	Habitat Management	Grazing Low/No Input Management	Commons	Context: Historic AES	Count
2013-16	0	0	0	0	12
2013-16	0	0	0	1	8
2013-16	0	0	1	0	16
2013-16	0	1	0	1	5
2013-16	1	0	0	0	2
2013-16	1	0	0	1	2
2013-16	1	0	1	0	3
2021-23	0	0	0	0	15
2021-23	0	0	0	1	2
2021-23	0	0	1	0	9
2021-23	0	1	0	1	7
2021-23	1	0	0	0	3
2021-23	1	0	0	1	5
2021-23	1	0	1	0	4

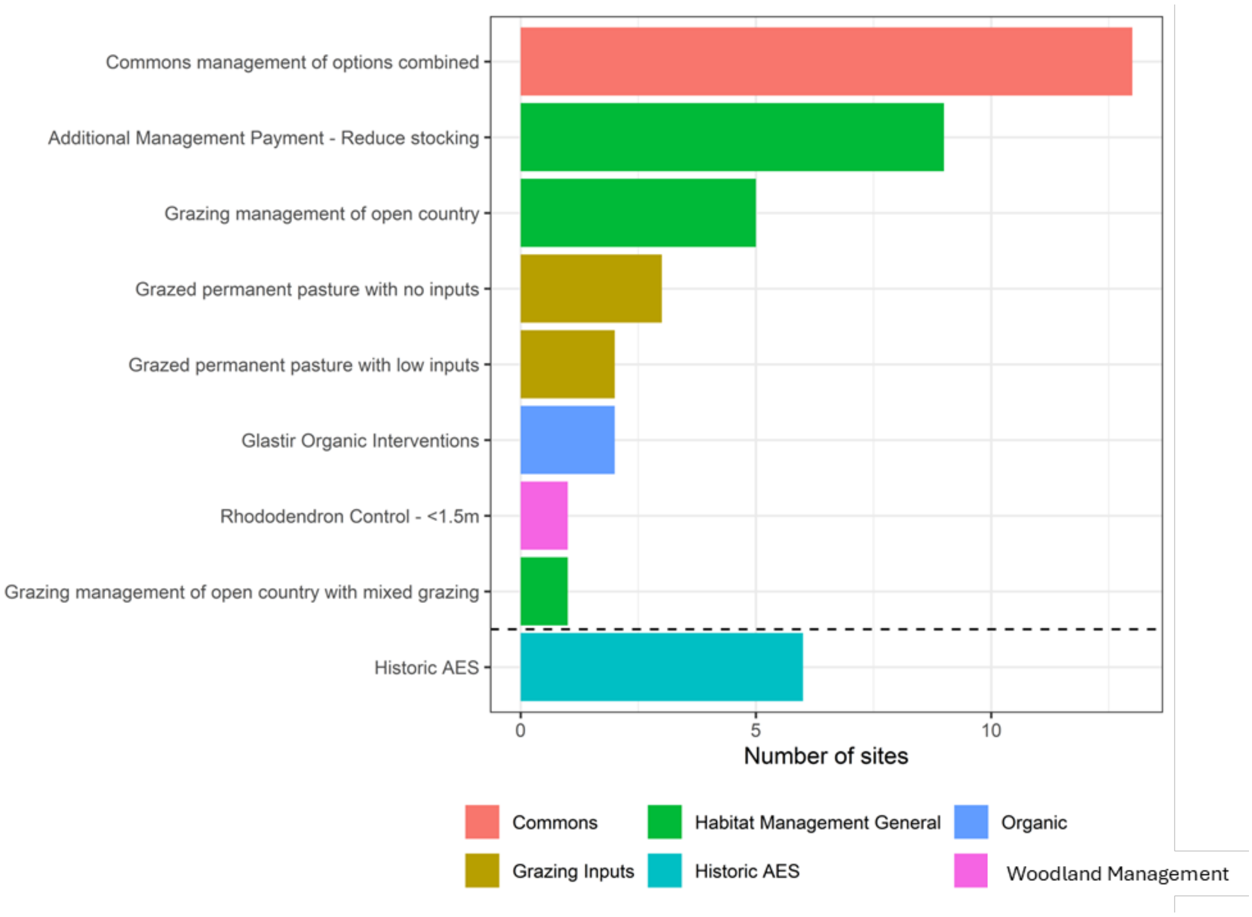

Figure 4-20 Action frequency in Glastir bundles present in Bracken for re-surveyed plots. The Glastir Habitat Management bundle had the highest uptake in Bracken, dominated by the actions "Reducing stocking" and "Grazing management of open country". The Commons bundle had the second highest uptake. The Glastir Grazing Inputs Management bundle contained the two actions Grazed permanent pasture with no inputs or low inputs. The Woodland management bundle was not tested for Bracken due to low representation in the dataset.

Table 4-14 Glastir analysis for topsoil indicators for Bracken. Glastir management bundles assessed for effects on topsoil indictors are shown. Context effect was tested using information related to participation in historic agri-environment schemes.

		Habitat Management		Grazing Low/No Input Management		Commons		Context: Historic AES	
Habitat	**Indicator**	**Glastir effect**	**P value**	**Glastir effect**	**P value**	**Glastir effect**	**P value**	**AES effect**	**P value**
Bracken	**Carbon (g/kg, from organic matter)**	-10.35	0.750	-6.49	0.79	17..7	<0.010	12.11	0.310
	pH in water	-0.24	0.270	0.1	0.760	0.24	0.240	-0.31	0.310
	N (g/100g dry soil)	-0.03	0.760	0.23	0.06	0.01	0.870	-0.03	0.710
	Carbon density (tC/ha)	-0.06	0.440	-0.11	0.240	0.02	0.670	0.01	0.970
	Bulk density (g/cm3)	-0.06	0.440	-0.11	0.240	0.02	0.670	0.01	0.970

4.5.2.1 Topsoil Carbon concentration

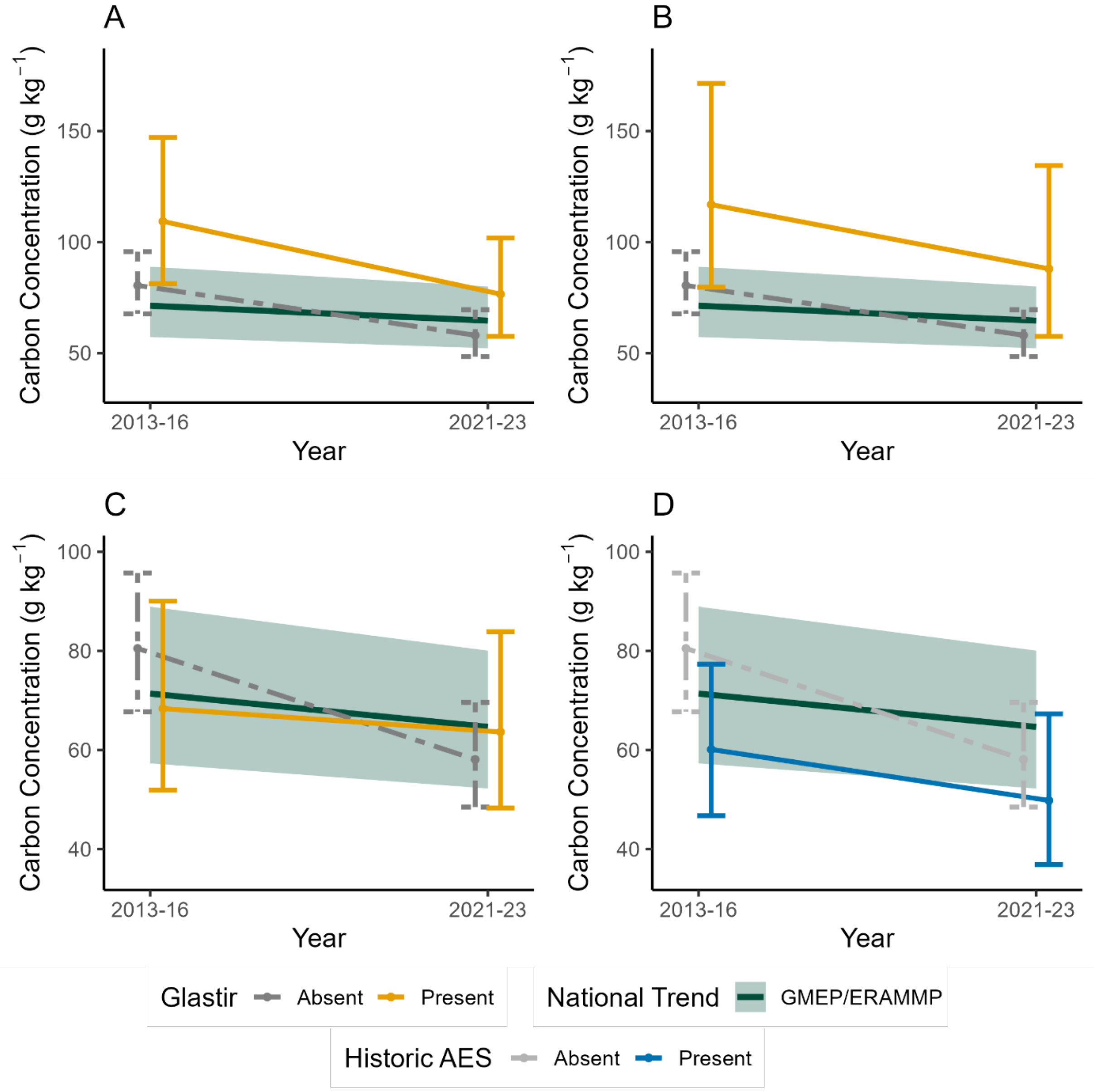

Figure 4-21 Trend in topsoil carbon concentration between 2013-16 and 2021-23 in Bracken showing both national trend and effect of the Glastir Habitat Management bundles A) Glastir Habitat Management, B) Glastir Grazing Low/No Inputs Management, C) Commons, and D) presence in historic agri-environment schemes (AES).

4.5.2.2 Topsoil pH in Water

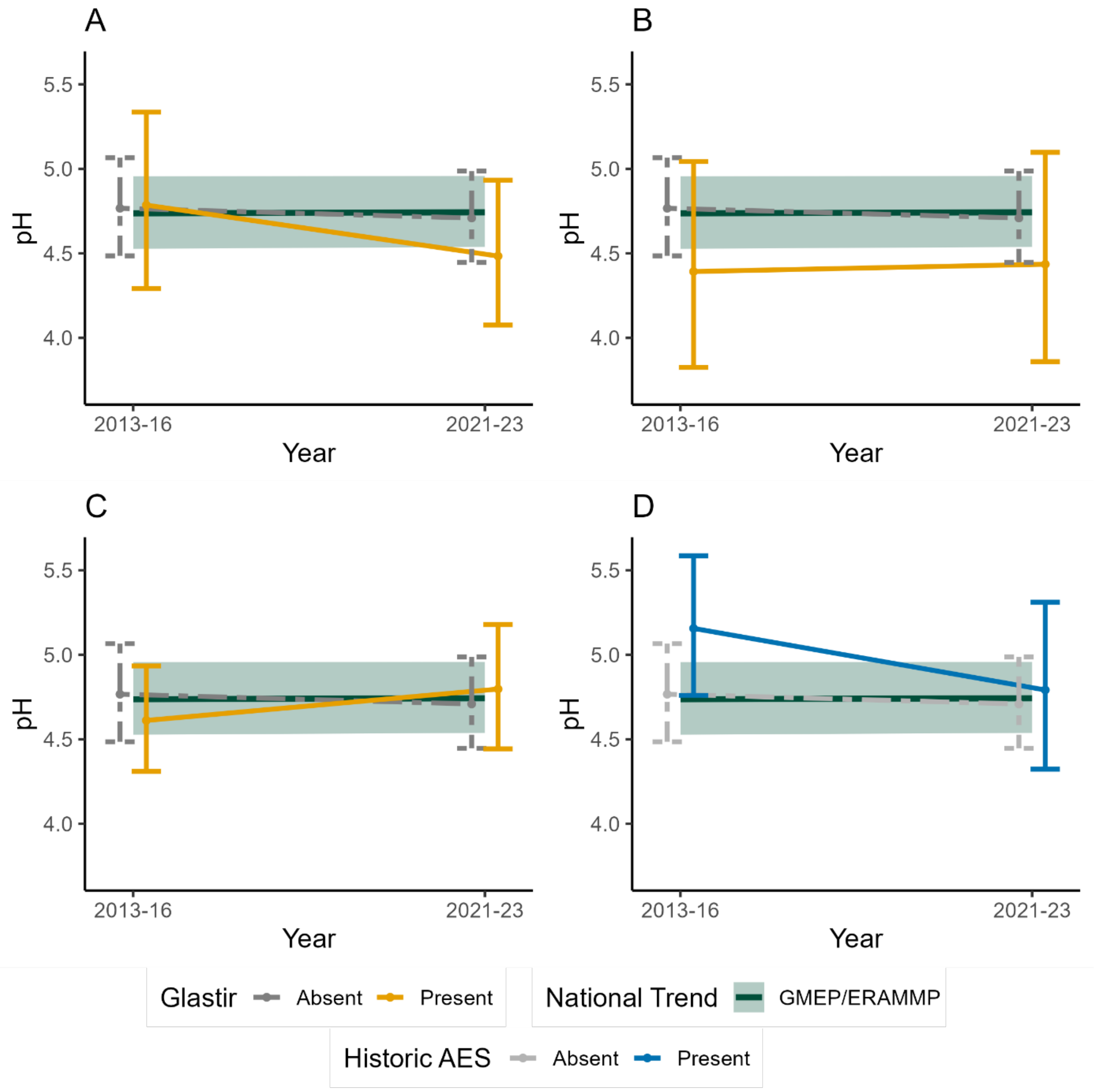

Figure 4-22 Trend in topsoil pH between 2013-16 and 2021-23 in Bracken showing both national trend and effect of the Glastir Habitat Management bundles A) Glastir Habitat Management, B) Glastir Grazing Low/No Inputs Management, C) Commons, and D) presence in historic agri-environment schemes (AES).

4.5.2.3 Topsoil Nitrogen Concentration

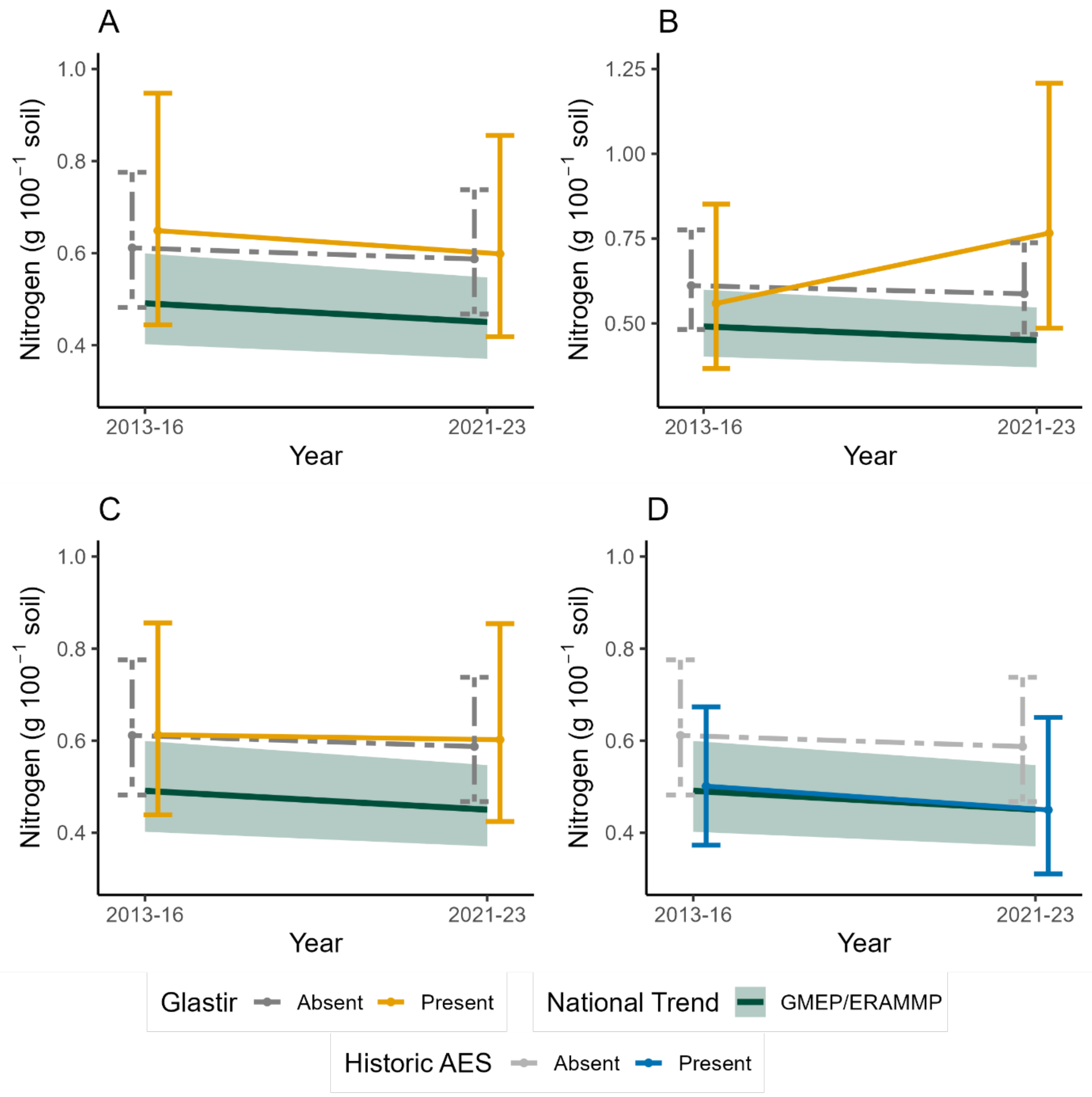

Figure 4-23 Trend in topsoil nitrogen concentration between 2013-16 and 2021-23 in Bracken showing both national trend and effect of the Glastir Habitat Management bundles A) Glastir Habitat Management, B) Glastir Grazing Low/No Inputs Management, C) Commons, and D) presence in historic agri-environment schemes (AES).

4.5.2.4 Topsoil Carbon Density

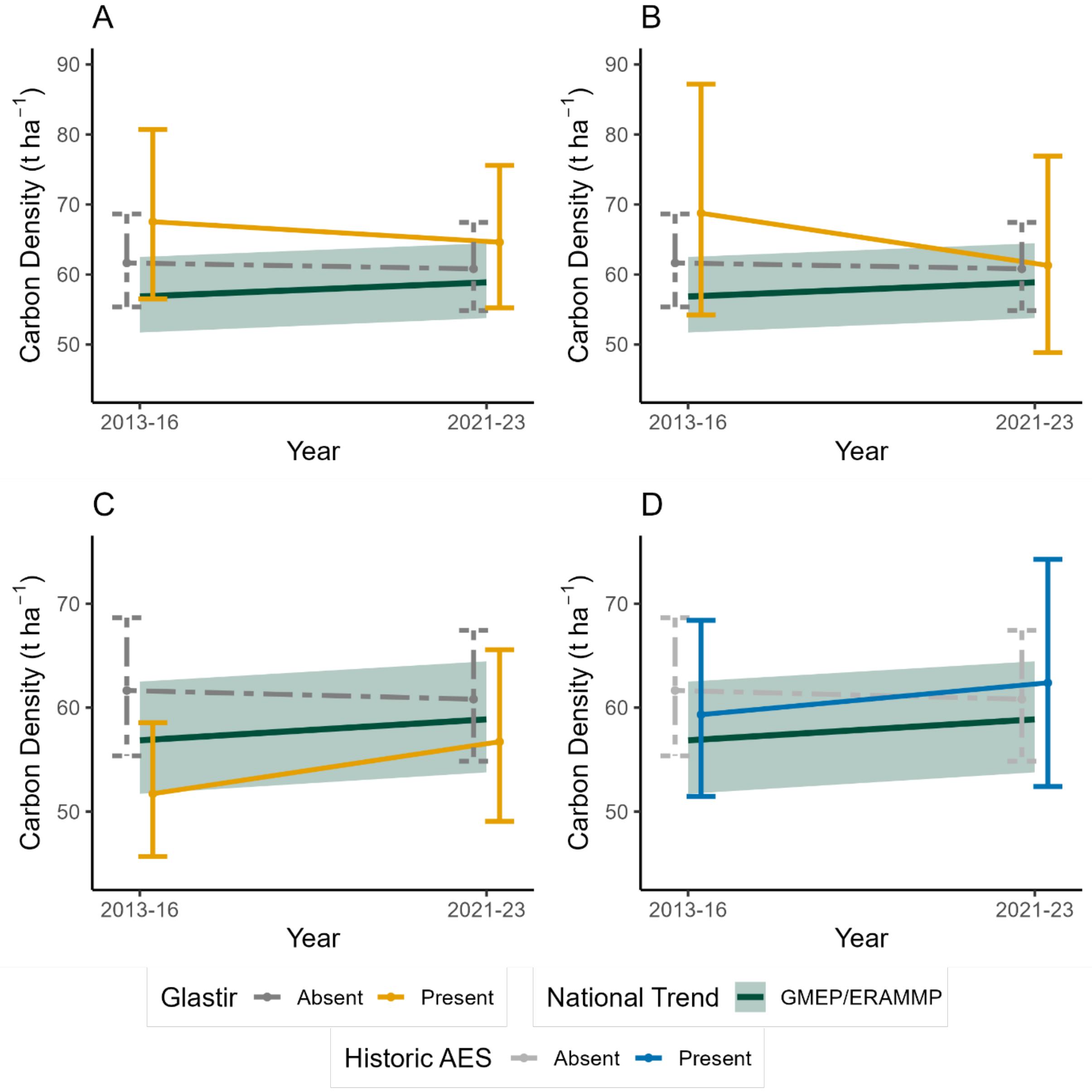

Figure 4-24 Trend in topsoil carbon density between 2013-16 and 2021-23 in Bracken showing both national trend and effect of the Glastir Habitat Management bundles A) Glastir Habitat Management, B) Glastir Grazing Low/No Inputs Management, C) Commons, and D) presence in historic agri-environment schemes (AES).

4.5.2.5 Topsoil Bulk Density

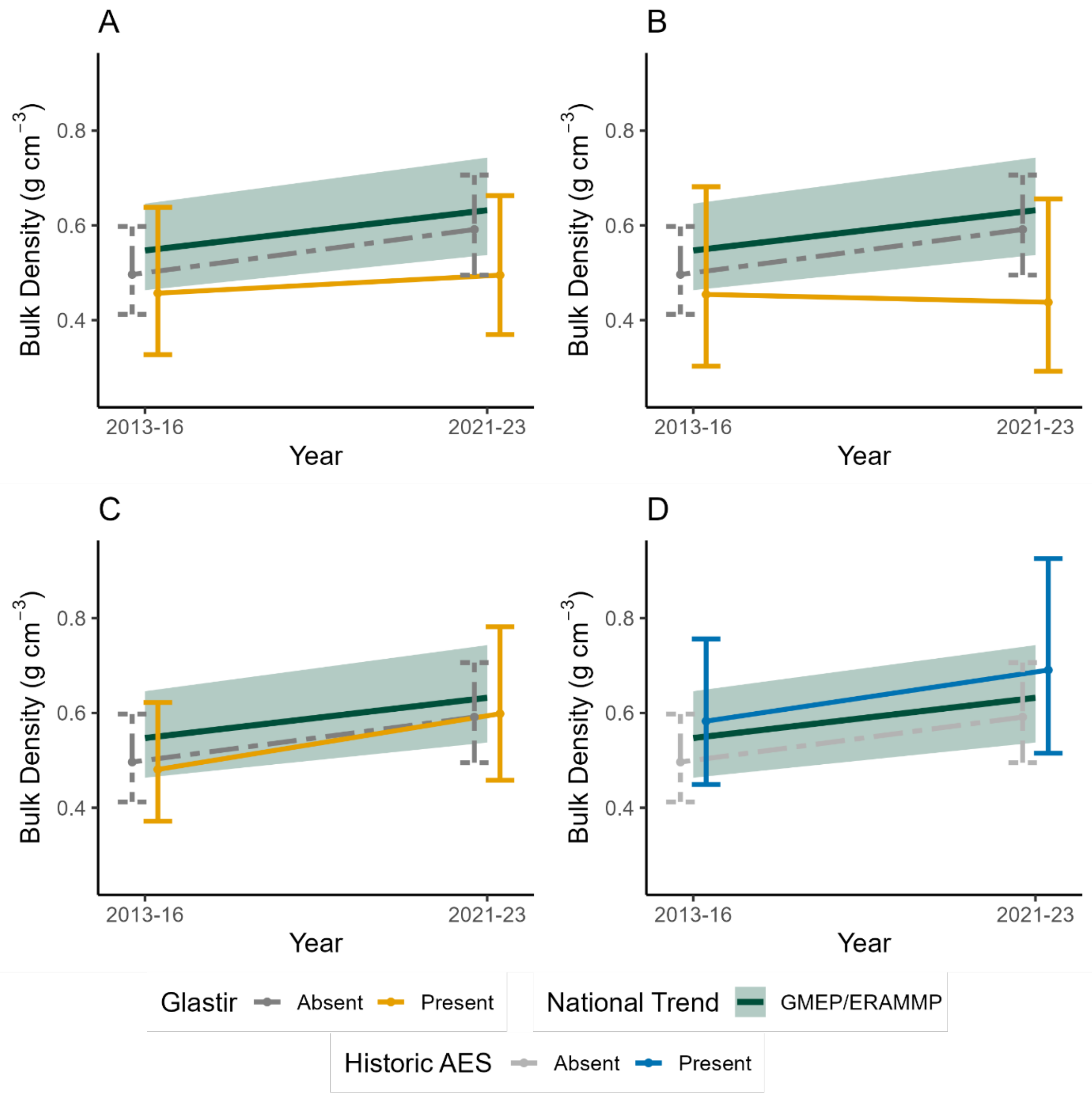

Figure 4-25 Trend in topsoil bulk density between 2013-16 and 2021-23 in Bracken showing both national trend and effect of the Glastir Habitat Management bundles A) Glastir Habitat Management, B) Glastir Grazing Low/No Inputs Management, C) Commons, and D) presence in historic agri-environment schemes (AES).

4.6 Fen, Marsh, Swamp

4.6.1 National Trend

Table 4-15 Long-term and short-term trends in topsoil indicators for Fen, Marsh, Swamp. Long-term data and trends in indicators for Fen, Marsh, Swamp were not available from Emmett et al. 2010 using the Countryside survey for Wales 1978 to 2007. Data analysis from this report cover the time periods 2013-16 (GMEP) and 2021-23 (ERAMMP). Models were run for each soil health indicator and Mean values, minimum and maximum confidence intervals (CI) were extracted and the mean change estimated. The p-value for the mean change in each soil health indicator is reported. No data are shown as grey boxes.

			Countryside survey				Trend 1978-90-2007		2013-16			2021-23			Trend 2016-2022	
Asset class	Habitat	Indicator	1978	1990	1998	2007	Mean change	P value	Mean	min CI	max CI	Mean	min CI	max CI	Mean change	P value
MMH	Fen, Marsh, Swamp	Carbon (g/kg, from organic matter)							156.6	112.1	218.9	149.1	106.5	208.7	-7.5	0.459
		pH in water							5.37	5.14	5.61	5.21	4.99	5.45	-0.16	0.082
		N (g/100g dry soil)							0.98	0.75	1.28	1.03	0.79	1.35	0.05	0.515
		Carbon density (tC/ha)							55.9	49.0	63.7	65.6	57.5	74.8	9.7	0.001
		Bulk density (g/cm3)							0.24	0.16	0.35	0.30	0.20	0.45	0.06	0.000

4.6.2 Glastir Analysis

The Glastir impacts on Fen, Marsh, Swamp topsoil indicators was assessed using the Habitat Management bundle, the Grazing Lo/No Inputs Management bundle, and the Commons bundle. The presence of historic AES schemes on topsoil indicators was assessed too. The Woodland management bundle was not analysed due to low action frequency representation in our dataset. The Organics bundle was not analysed due to low representation in re-surveyed plots.

The Habitat Management bundle was the largest bundle and associated with a total of seven actions, the three most common actions being: Reduced stocking, Grazing management of open country, and Lowland marshy grassland. The Grazing Lo/No Inputs Management bundle was mainly associated with the action on Grazed permanent pasture with no inputs. The Organics bundle is represented by the action on “Glastir Organic Interventions”, and the Commons bundle is represented by the action “Commons management of options combined”.

Table 4-16 Data coverage available for the Glastir analysis for Fen, Marsh and Swamp. The Glastir Habitat Management, Glastir Grazing Input management, and Commons bundle were analysed for Glastir impacts on topsoils in Fen, Marsh and Swamp. Presence of historic AES was also assessed for its impact. Glastir bundle or historic AES present (0 = no, 1 = yes), and count for combinations for each time point (2013-16 and 2021-23). Information on the Glastir Organics bundle was included to show that uptake of organic management increased in the dataset between 2013-16 (GMEP) and 2021-23 (ERAMMP).

National Trend	Habitat Management	Grazing Low/No Input Management	Organics	Commons	Context: Historic AES	Count
2013-16	0	0	0	0	0	20
2013-16	0	0	0	0	1	11
2013-16	0	0	0	1	0	11
2013-16	0	0	0	1	1	1
2013-16	0	1	0	0	0	3
2013-16	0	1	0	0	1	2
2013-16	1	0	0	0	0	3
2013-16	1	0	0	0	1	5
2013-16	1	0	0	1	0	1
2013-16	1	0	1	0	1	2
2013-16	1	1	0	0	1	1
2021-23	0	0	0	0	0	11
2021-23	0	0	0	0	1	5
2021-23	0	0	0	1	0	4
2021-23	0	1	0	0	0	1
2021-23	0	1	0	0	1	2
2021-23	0	1	1	0	1	1
2021-23	1	0	0	0	0	4
2021-23	1	0	0	0	1	9
2021-23	1	0	1	0	1	7
2021-23	1	1	0	0	0	2
2021-23	1	1	0	0	1	1

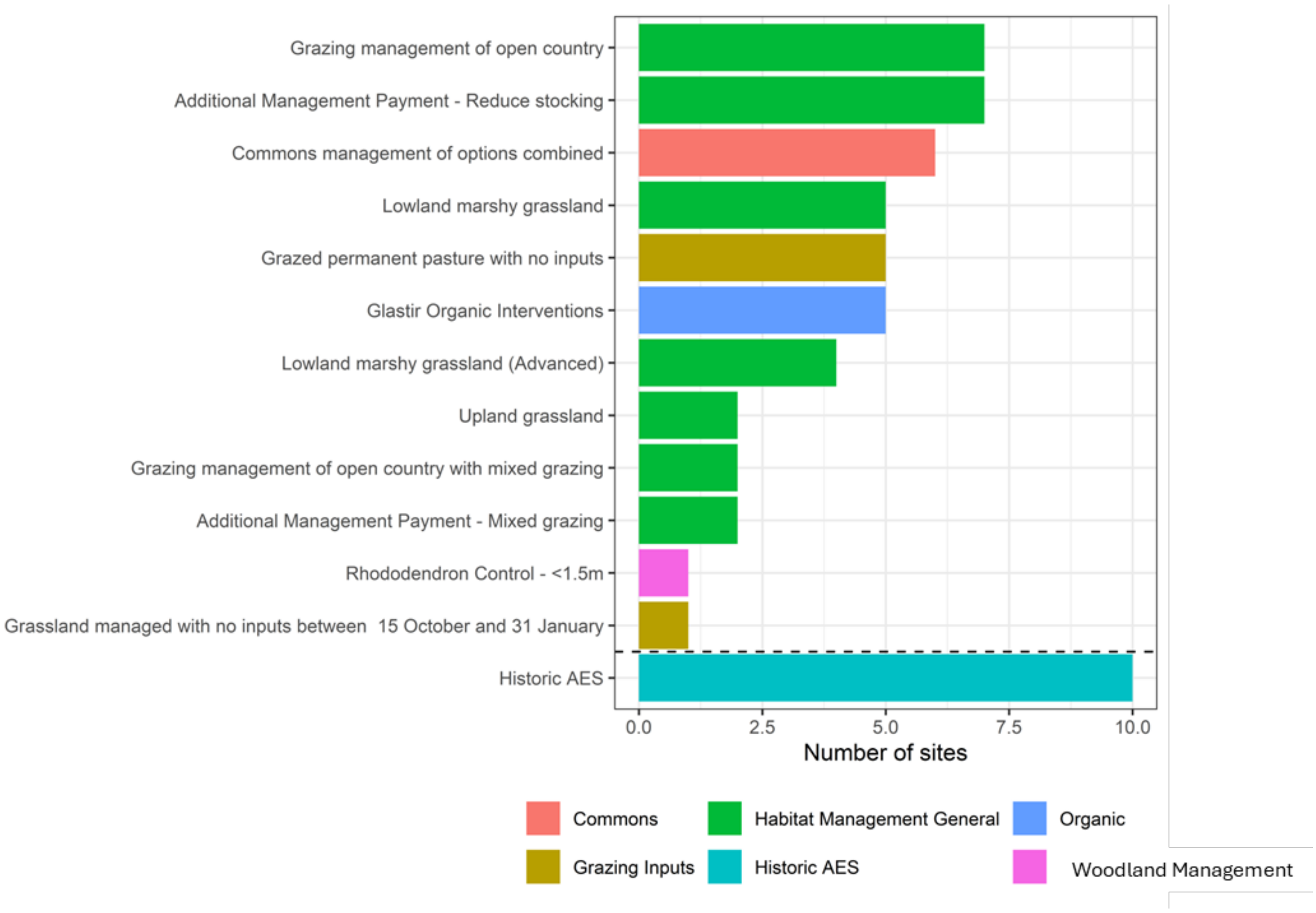

Figure 4-26 Action frequency in Glastir bundles present in Fen, Marsh and Swamp for re-surveyed plots. The Woodland management bundle and the Organics bundle were not analysed due to low action frequency representation between surveys in our dataset.

Table 4-17 Glastir analysis for topsoil health indicators in Fen, Marsh, Swamp. The models test for the effect of Glastir bundle compared to plots without the Glastir bundle on topsoil health indicators. Context effect was tested using information related to participation in historic agri-environment schemes (AES). The Glastir and Context effect was tested for 2013-16 (GMEP) compared to 2021-23 (ERAMMP). The Glastir bundle/Context effect and the associated P values are reported for each topsoil health indicator.

		Habitat Management		Grazing Lo/No Input Management		Commons		Context: Historic AES	
Habitat	Indicator	Glastir effect	P value	Glastir effect	P value	Glastir effect	P value	AES effect	P value
Fen, Marsh, Swamp	Carbon (g/kg, from organic matter)	15.88	0.340	-22.52	0.080	10.42	0.750	-12.67	0.380
	pH in water	-0.17	0.400	0.970	<0.01	0.26	0.400	0.26	0.190
	N (g/100g dry soil)	0.3	0.080	-0.16	0.510	0.55	0.060	0.03	0.920
	Carbon density (tC/ha)	-0.01	0.570	-13.51	0.040	-9.57	0.340	-5.47	0.240
	Bulk density (g/cm3)	-0.06	0.580	-0.06	0.280	-0.09	0.500	0.02	0.770

4.6.2.1 Topsoil Carbon Concentration

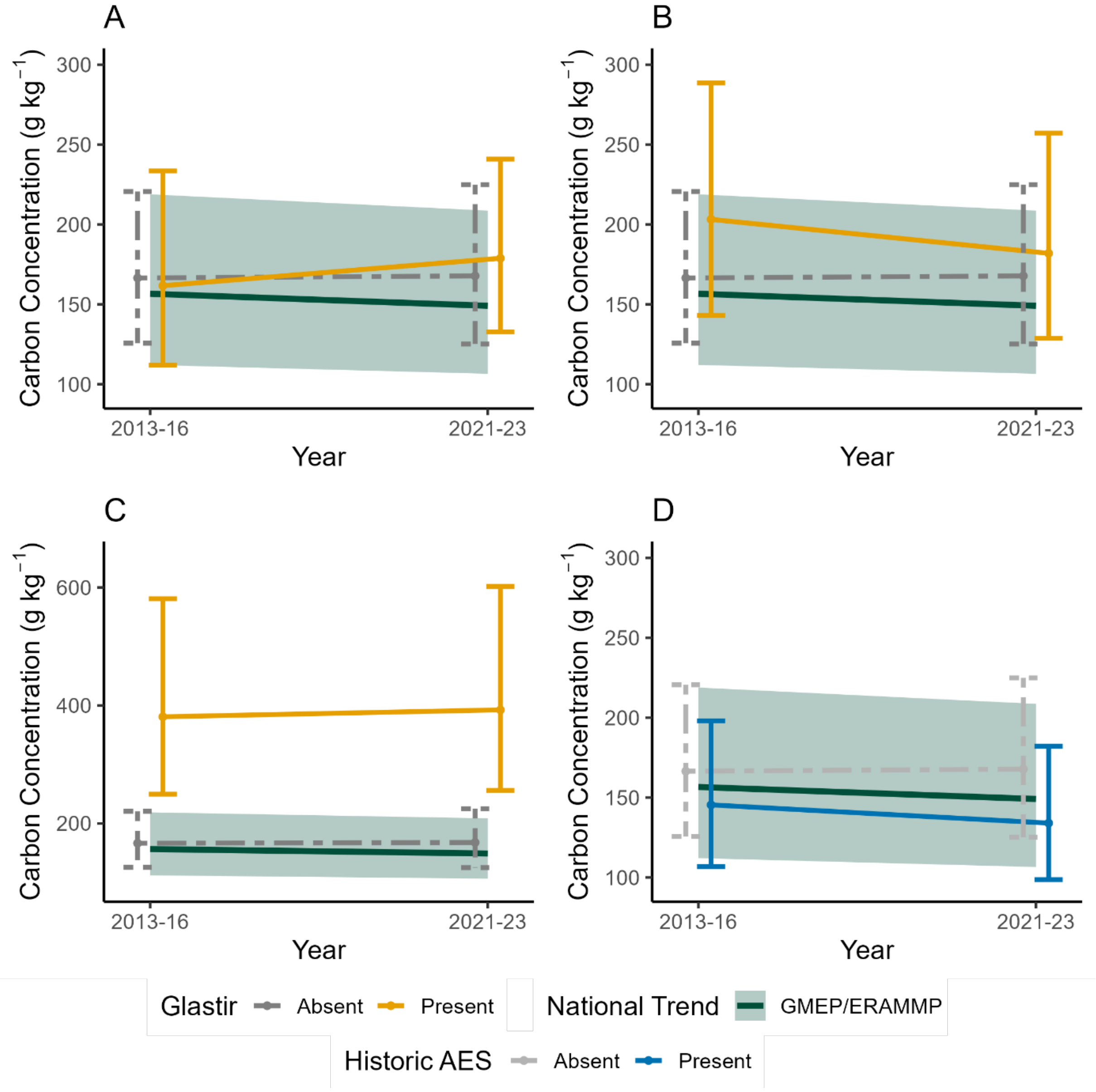

Figure 4-27 Trend in topsoil carbon concentration between 2013-16 and 2021-23 in Fen, Marsh and Swamp showing both national trend and effect of the Glastir Habitat Management bundles A) Glastir Habitat Management, B) Glastir Grazing Low/No Inputs Management, C) Commons, and D) presence in historic agri-environment schemes (AES).

4.6.2.2 Topsoil pH in Water

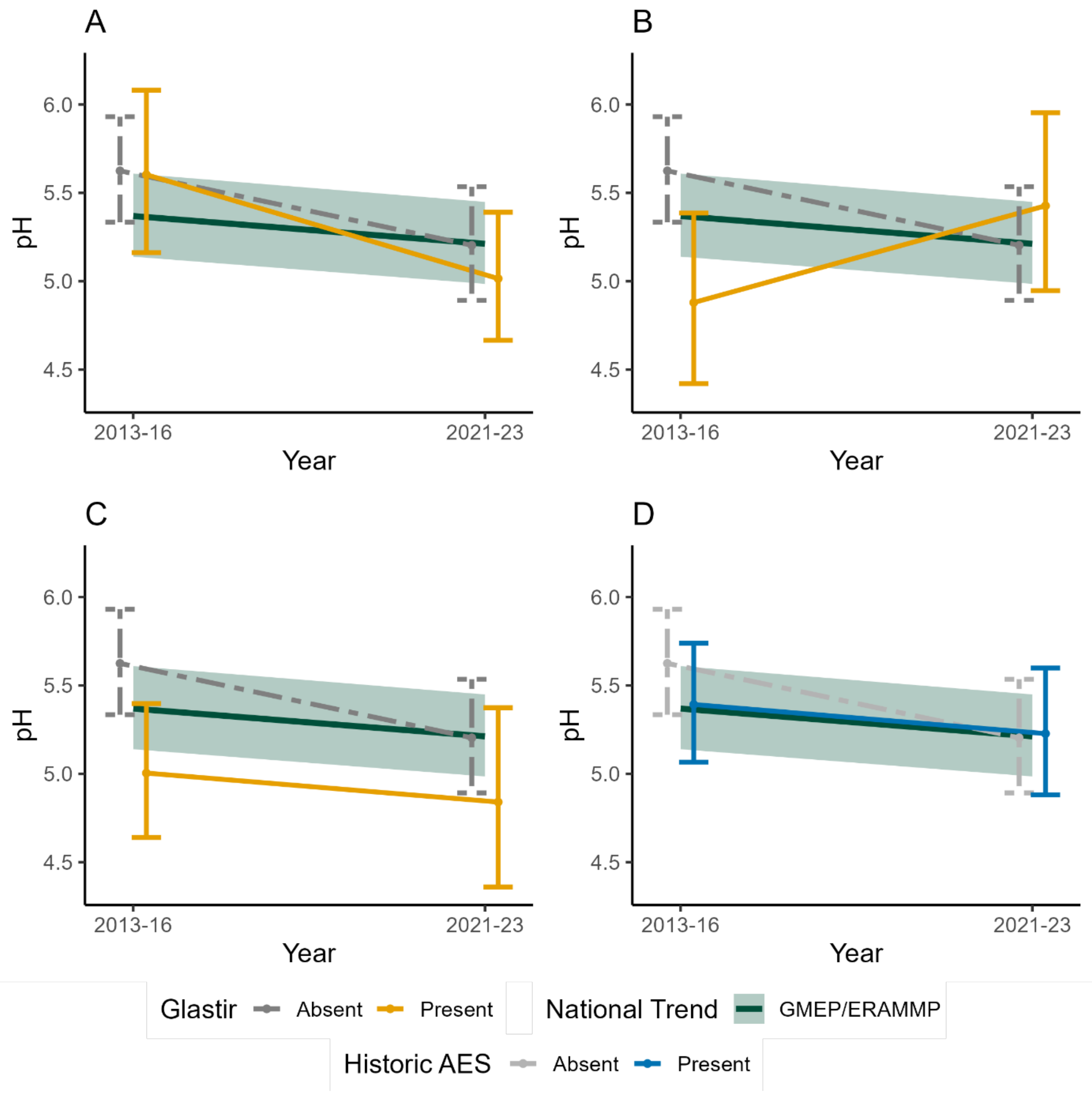

Figure 4-28 Trend in topsoil pH between 2013-16 and 2021-23 in Fen, Marsh and Swamp showing both national trend and effect of the Glastir Habitat Management bundles A) Glastir Habitat Management, B) Glastir Grazing Low/No Inputs Management, C) Commons, and D) presence in historic agri-environment schemes (AES).

4.6.2.3 Topsoil Nitrogen Concentration

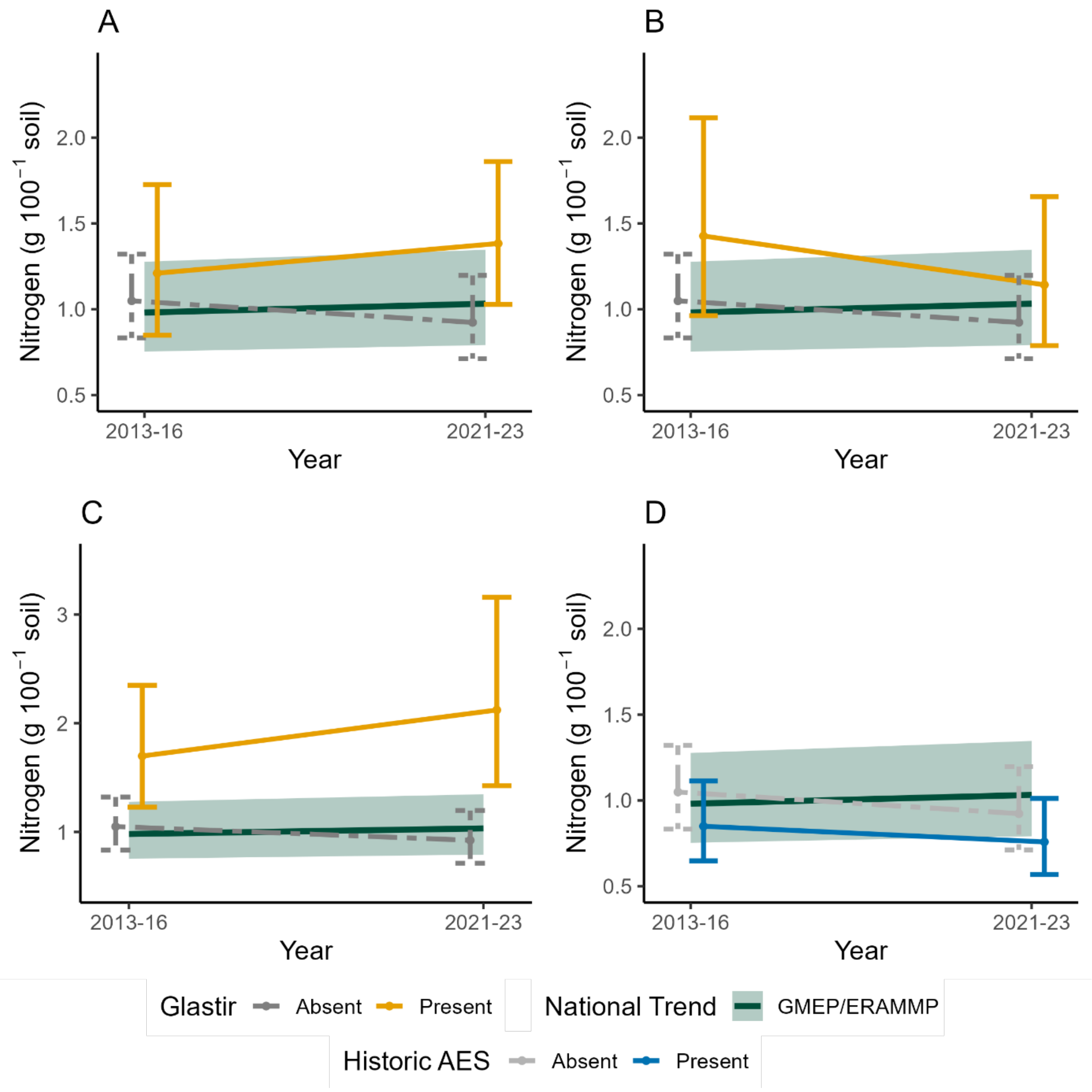

Figure 4-29 Trend in topsoil nitrogen concentration between 2013-16 and 2021-23 in Fen, Marsh and Swamp showing both national trend and effect of the Glastir Habitat Management bundles A) Glastir Habitat Management, B) Glastir Grazing Low/No Inputs Management, C) Commons, and D) presence in historic agri-environment schemes (AES).

4.6.2.4 Topsoil Carbon Density

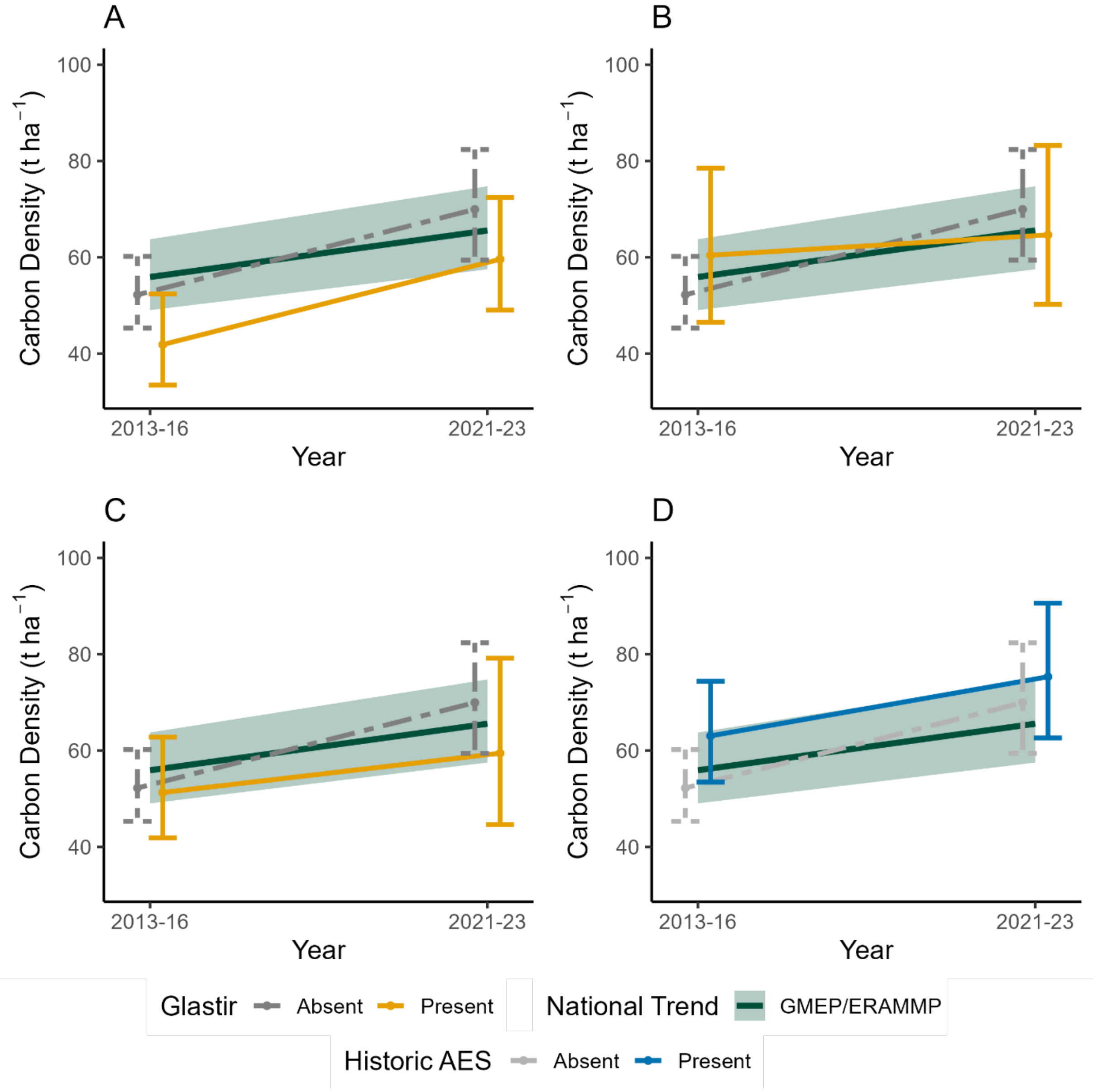

Figure 4-30 Trend in topsoil carbon density between 2013-16 and 2021-23 in Fen, Marsh and Swamp showing both national trend and effect of the Glastir Habitat Management bundles A) Glastir Habitat Management, B) Glastir Grazing Low/No Inputs Management, C) Commons, and D) presence in historic agri-environment schemes (AES).

4.6.2.5 Topsoil Bulk Density

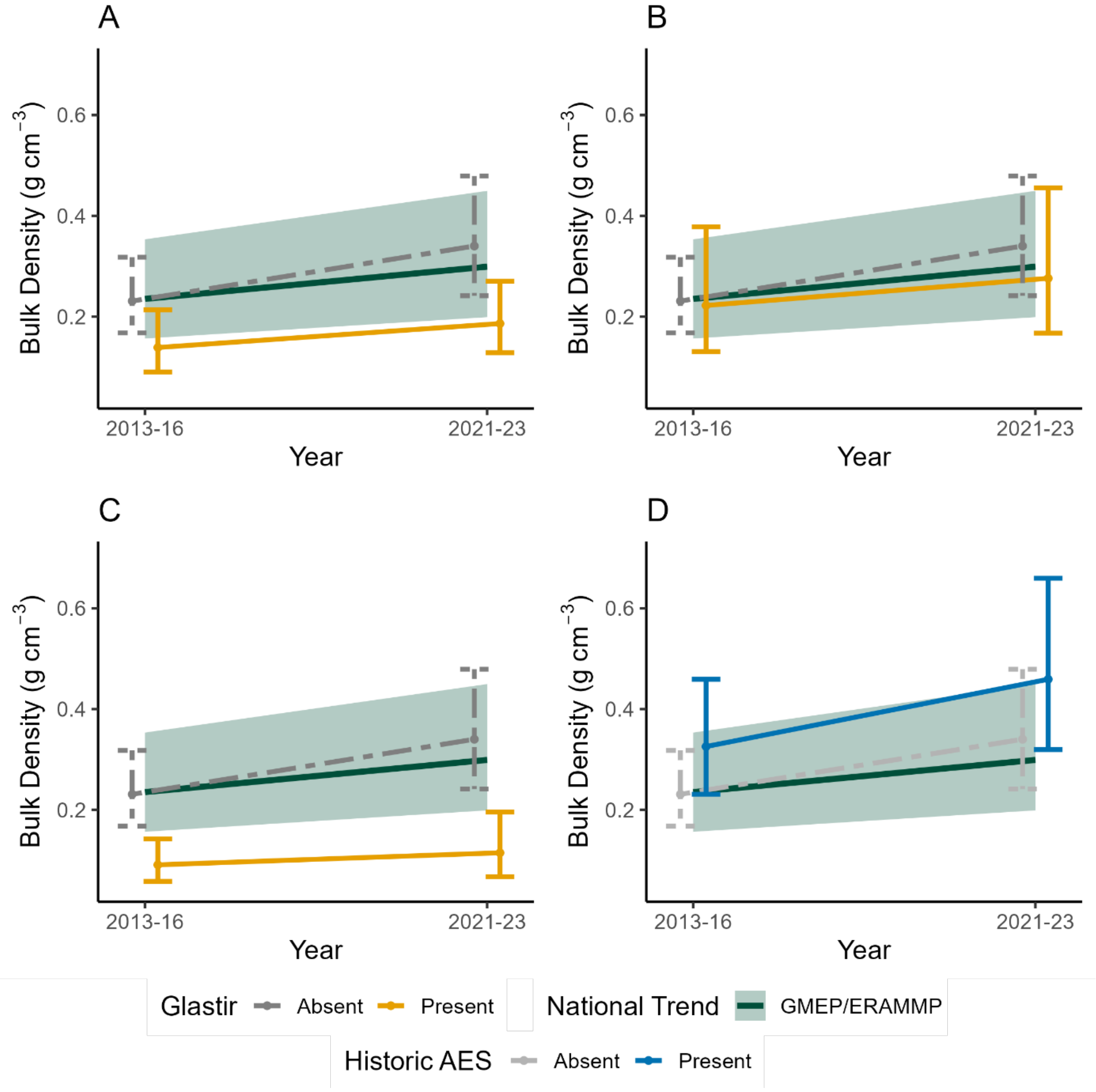

Figure 4-31 Trend in topsoil bulk density between 2013-16 and 2021-23 in Fen, Marsh and Swamp showing both national trend and effect of the Glastir Habitat Management bundles A) Glastir Habitat Management, B) Glastir Grazing Low/No Inputs Management, C) Commons, and D) presence in historic agri-environment schemes (AES).

4.7 Acid Grassland

4.7.1 National Trend

Table 4-18 Long-term and short-term trends in topsoil indicators for Acid Grassland. Long-term data and trends in indicators for Acid Grassland were extracted from Emmett et al. 2010 using the Countryside survey for Wales 1978 to 2007. Data analysis from this report cover the time periods 2013-16 (GMEP) and 2021-23 (ERAMMP). Models were run for each soil health indicator and Mean values, minimum and maximum confidence intervals (CI) were extracted and the mean change estimated. The p-value for the mean change in each soil health indicator is reported. No data are shown as grey boxes.

			Countryside survey				Trend 1978-90-2007		2013-16			2021-23			Trend 2016-2022	
Asset class	Habitat	Indicator	1978	1990	1998	2007	Mean change	P value	Mean	min CI	max CI	Mean	min CI	max CI	Mean change	P value
Semi-natural Grassland	Acid Grassland	Carbon (g/kg, from organic matter)	198.2		208.2	207.4	9.2	>0.05	135.4	106.8	171.7	129.3	101.4	164.8	-6.1	0.570
		pH in water	4.34		4.41	4.74	0.40	>0.05	4.79	4.63	4.96	4.56	4.40	4.72	-0.23	0.000
		N (g/100g dry soil)							0.80	0.66	0.98	0.77	0.63	0.95	-0.03	0.468
		Carbon density (tC/ha)	89.2		92.8	83.8	-5.4	>0.05	69.5	63.1	76.6	76.8	69.7	84.7	7.3	0.042
		Bulk density (g/cm3)							0.40	0.34	0.48	0.45	0.37	0.54	0.04	0.166

4.7.2 Glastir Analysis

The Glastir impacts on Acid Grassland topsoil indicators were assessed using the Habitat Management bundle, the Grazing Lo/No Inputs Management bundle, and the Organics and Commons bundles. The presence in historic AES schemes was assessed too. The Woodland management bundle was not analysed for Glastir impacts on Acid Grassland topsoil indicators due to low representation in the dataset.

The Habitat Management bundle was the largest bundle and associated with a total of eight actions, the two dominating actions being: Reduced stocking and Grazing management of open country. The Grazing Lo/No Inputs Management bundle was mainly associated with the action on Grazed permanent pasture with no inputs. The Organics bundle was represented by the action on “Glastir Organic Interventions”, and the Commons bundle was represented by the action “Commons management of options combined”.

Although the Glastir analysis included the of the Grazing Lo/No Inputs management bundle and the Organics bundle, representation in the dataset was low. Interpretation of these two bundles should be carried out with caution.

Table 4-19 Data coverage available for the Glastir analysis for Acid Grassland. The Glastir Habitat Management bundle, Glastir Grazing Lo/No Input management bundle, Organics and Commons bundles were analysed for Glastir impacts on topsoil indicators in Acid Grassland. Presence of historic AES was also assessed for its impact. Glastir bundle or historic AES present (0 = no, 1 = yes), and count for combinations for each time point (2013-16 and 2021-23).

National Trend	Habitat Management	Grazing Low/No Inputs Management	Organics	Commons	Context: Historic AES	Count
2013-16	0	0	0	0	0	43
2013-16	0	0	0	0	1	33
2013-16	0	0	0	1	0	28
2013-16	0	0	0	1	1	3
2013-16	0	0	1	0	1	1
2013-16	0	1	0	0	0	3
2013-16	0	1	0	0	1	4
2013-16	1	0	0	0	0	14
2013-16	1	0	0	0	1	37
2013-16	1	0	0	1	0	14
2013-16	1	0	1	0	1	12
2013-16	1	1	0	0	0	1
2021-23	0	0	0	0	0	33
2021-23	0	0	0	0	1	12
2021-23	0	0	0	1	0	7
2021-23	0	0	0	1	1	1
2021-23	0	0	1	0	1	1
2021-23	0	1	0	0	0	3
2021-23	0	1	0	0	1	1
2021-23	1	0	0	0	0	3
2021-23	1	0	0	0	1	28
2021-23	1	0	0	1	0	3
2021-23	1	0	1	0	0	1
2021-23	1	0	1	0	1	15
2021-23	1	1	0	0	0	1
2021-23	1	1	0	0	1	1

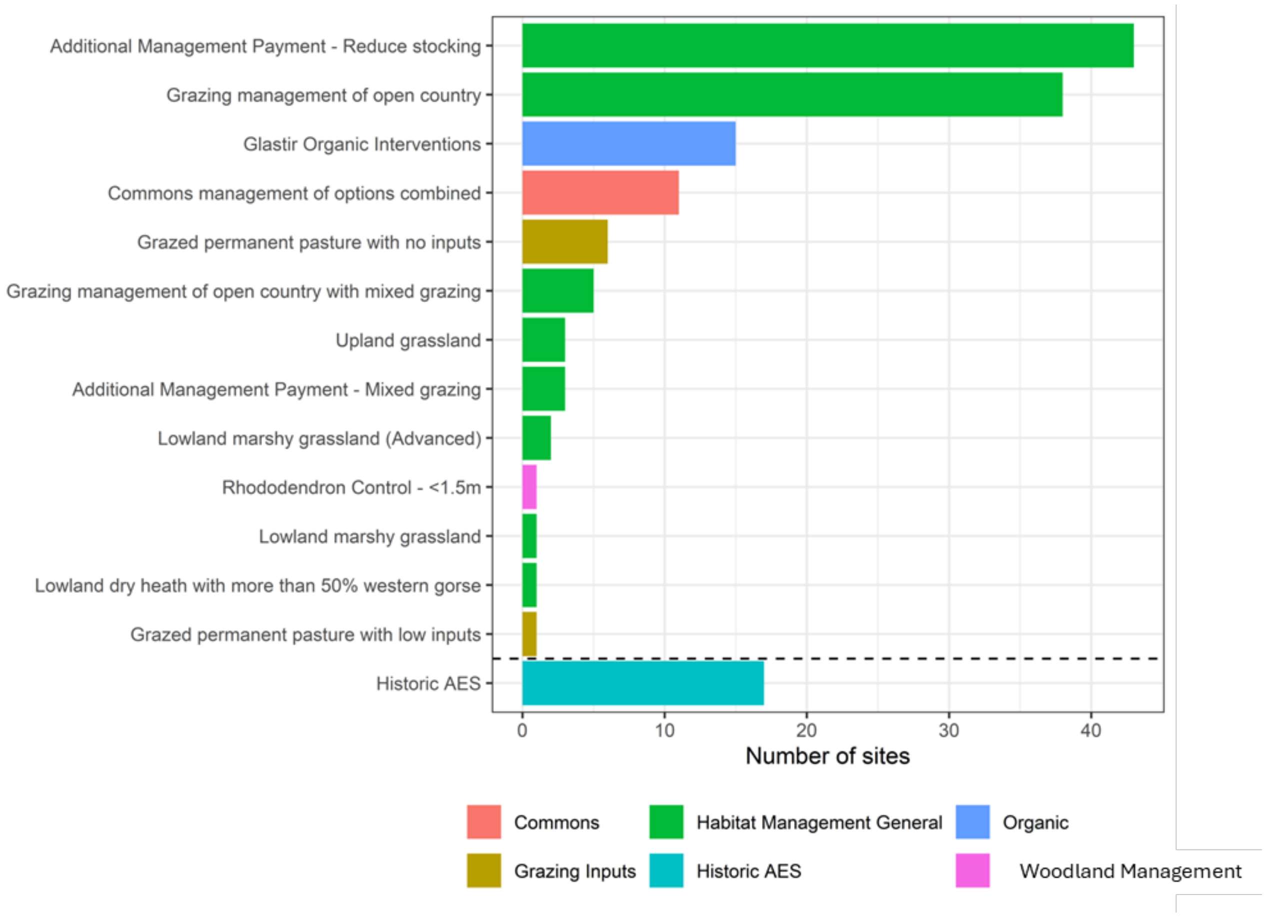

Figure 4-32 Action frequency in Glastir bundles present in Acid Grassland for direct repeat plots. The Woodland management bundle was not analysed for Glastir impacts on Acid Grassland topsoil indicators due to low representation in the dataset.

Table 4-20 Glastir analysis for topsoil health indicators in Acid Grassland. The models test for the effect of Glastir bundle compared to plots without the Glastir bundle on topsoil health indicators. Context effect was tested using information related to participation in historic agri-environment schemes (AES). The Glastir and Context effect was tested for 2013-16 (GMEP) compared to 2021-23 (ERAMMP). The Glastir bundle/Context effect and the associated P values are reported for each topsoil health indicator. Where Glastir bundles were not reprehensively covered in our dataset, these were not analysed and are greyed out in the table.

		Habitat Management		Grazing Lo/No Input Management		Organics		Commons		Context: Historic AES	
Habitat	Indicator	Glastir effect	P value	Glastir effect	P value	Glastir effect	P value	Glastir effect	P value	AES effect	P value
Acid Grassland	Carbon (g/kg, from organic matter)	-37.16	0.090	-39.42	0.400	18.18	0.580	-8.64	0.730		
	pH in water	0.06	0.580	0.04	0.770	-0.18	0.220	0.03	0.840	-0.15	0.100
	N (g/100g dry soil)	-0.11	0.340	0.04	0.770	-0.02	0.950	-0.1	0.370	0.12	0.180
	Carbon density (tC/ha)	-2.93	0.610	-11.04	0.300	15.43	0.080	-3.7	0.640	-0.38	0.910
	Bulk density (g/cm3)	0.08	0.070	-0.02	0.900	0.05	0.460	0.01	0.830	-0.07	0.180

4.7.2.1 Topsoil Carbon Concentration

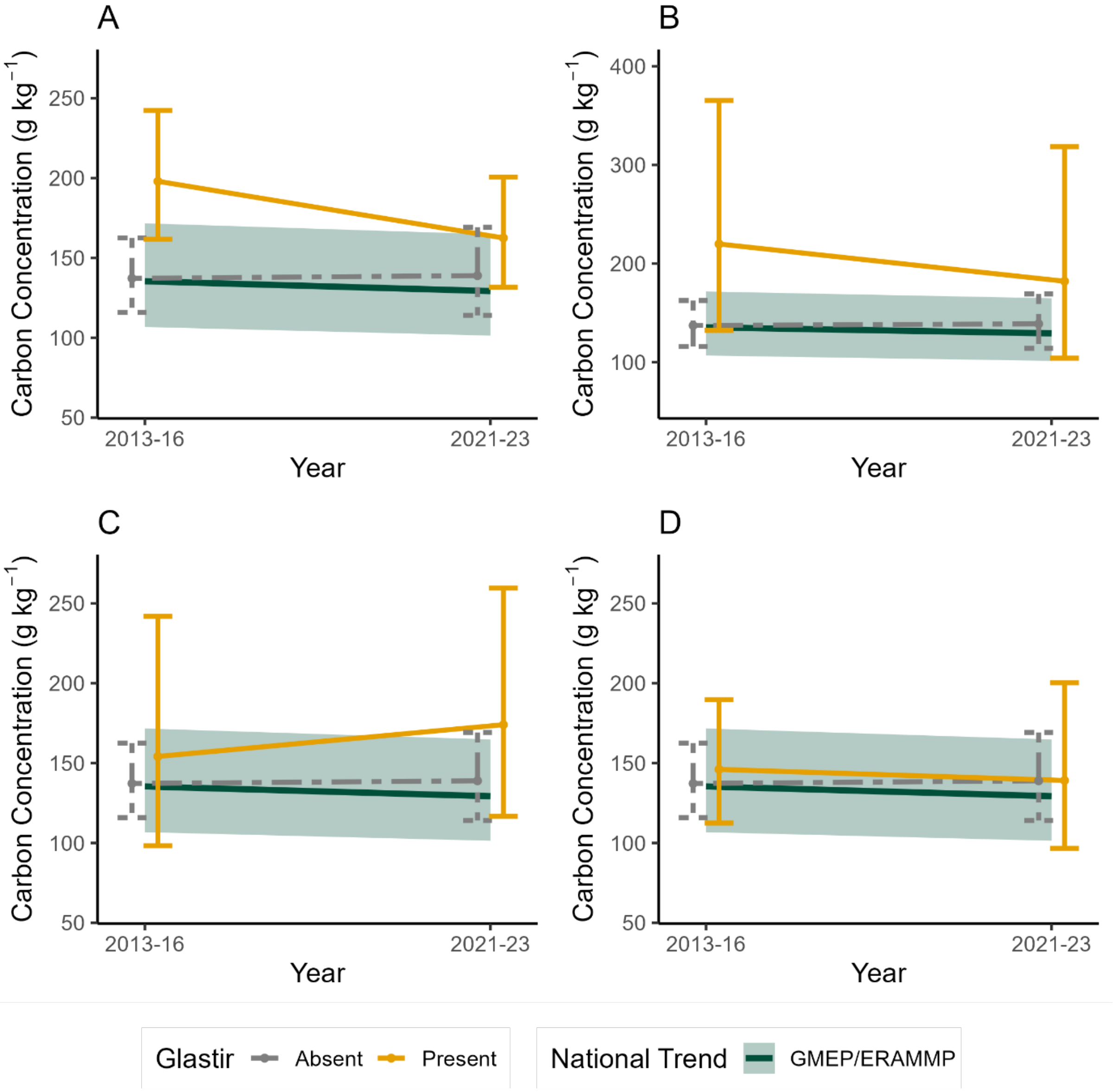

Figure 4-33 Trend in topsoil carbon concentration between 2013-16 and 2021-23 in Acid Grassland showing both national trend and effect of the Glastir bundles A) Glastir Habitat Management, B) Glastir Grazing Low/No Inputs Management, C) Organics, and D) Commons.

4.7.2.2 Topsoil pH in Water

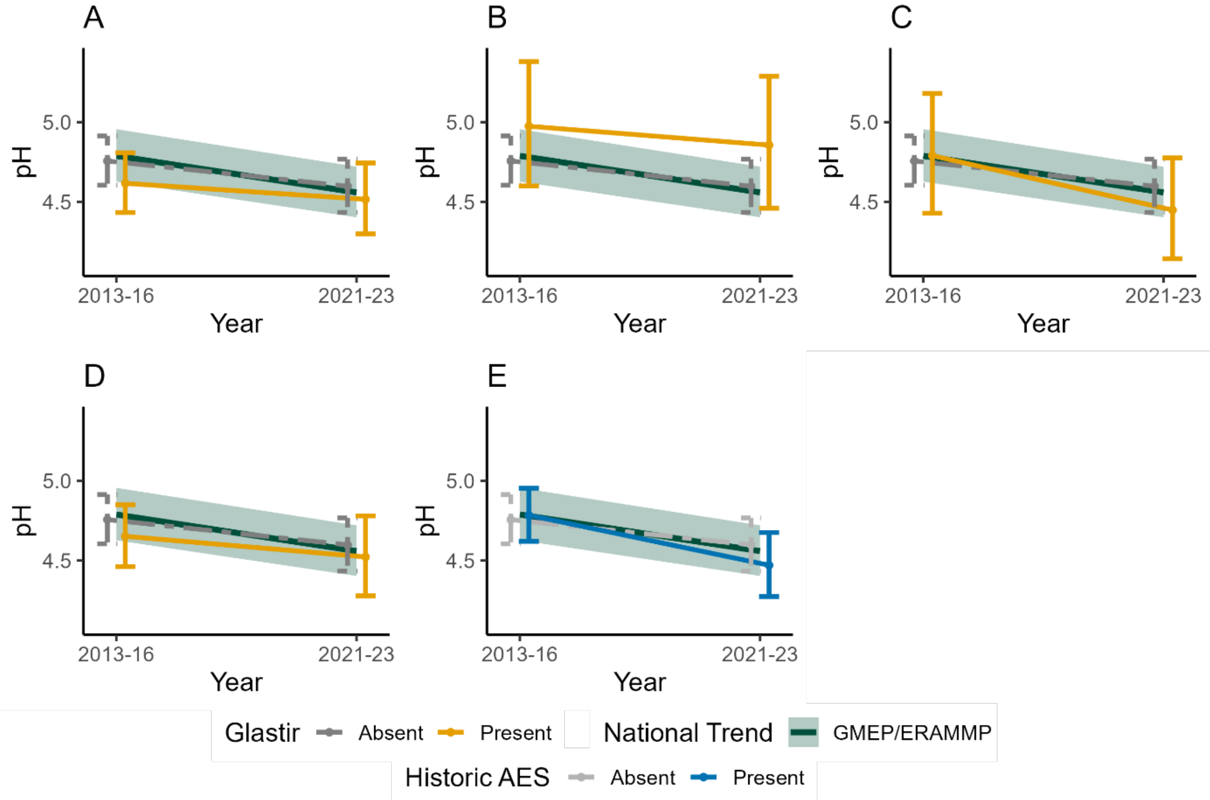

Figure 4-34 Trend in topsoil pH between 2013-16 and 2021-23 in Acid Grassland showing both national trend and effect of the Glastir bundles A) Glastir Habitat Management, B) Glastir Grazing Low/No Inputs Management, C) Organics, D) Commons, and E) presence in historic agri-environment schemes (AES).

4.7.2.3 Topsoil Nitrogen Concentration

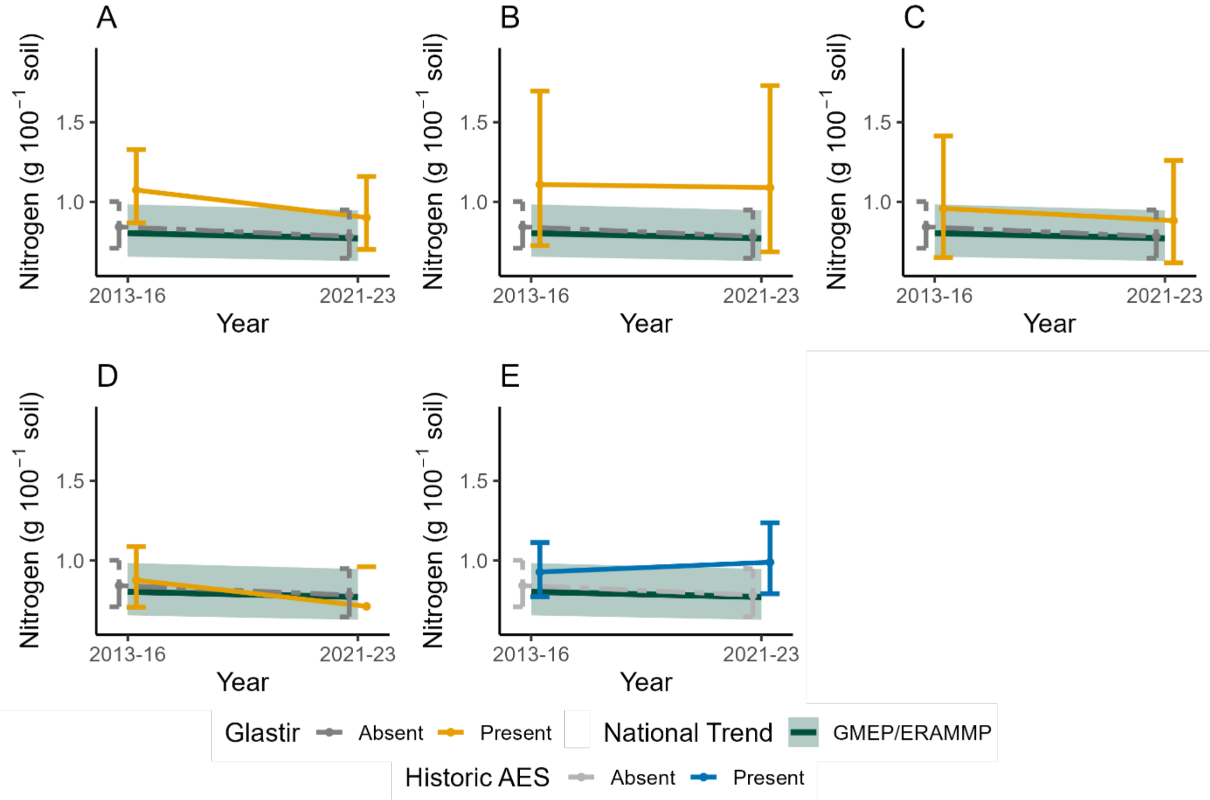

Figure 4-35 Trend in topsoil nitrogen concentration between 2013-16 and 2021-23 in Acid Grassland showing both national trend and effect of the Glastir bundles A) Glastir Habitat Management, B) Glastir Grazing Low/No Inputs Management, C) Organics, D) Commons, and E) presence in historic agri-environment schemes (AES).

4.7.2.4 Topsoil Carbon Density

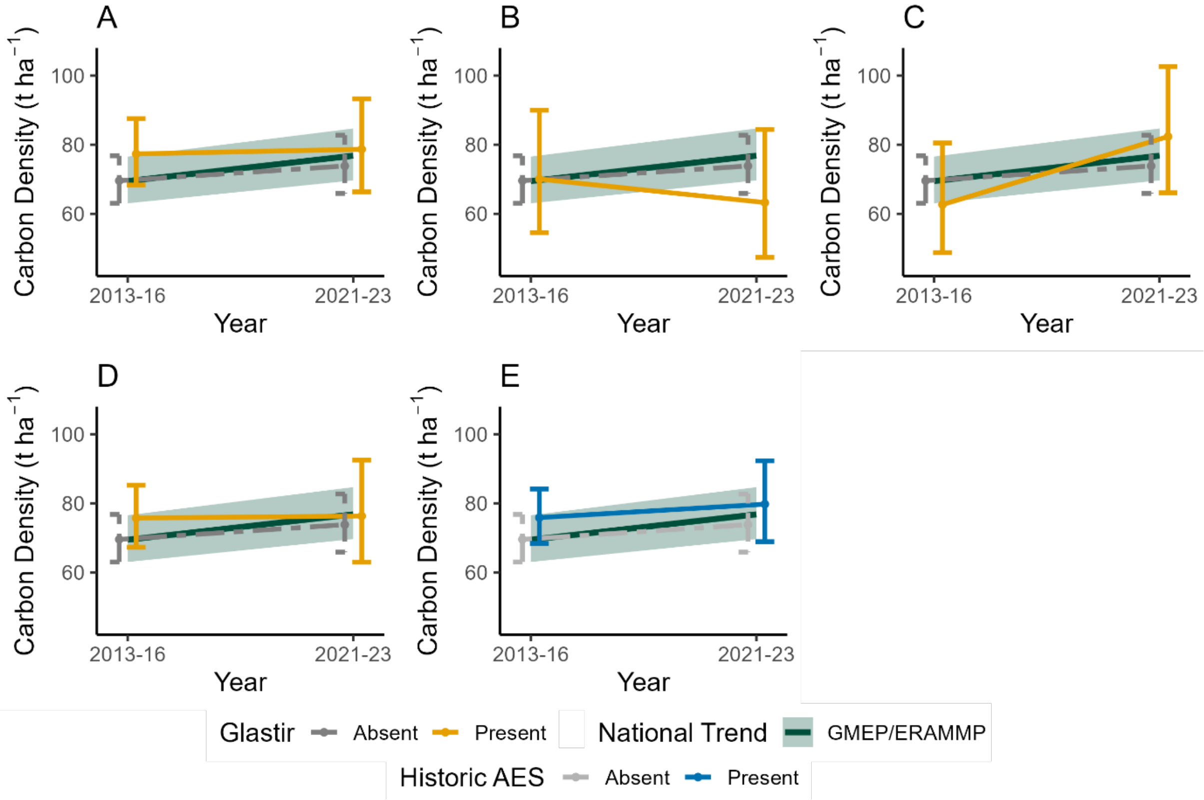

Figure 4-36 Trend in topsoil carbon density between 2013-16 and 2021-23 in Acid grassland showing both national trend and effect of the Glastir bundles A) Glastir Habitat Management, B) Glastir Grazing Low/No Inputs Management, C) Organics, D) Commons, and E) presence in historic agri-environment schemes (AES).

4.7.2.5 Topsoil Bulk Density

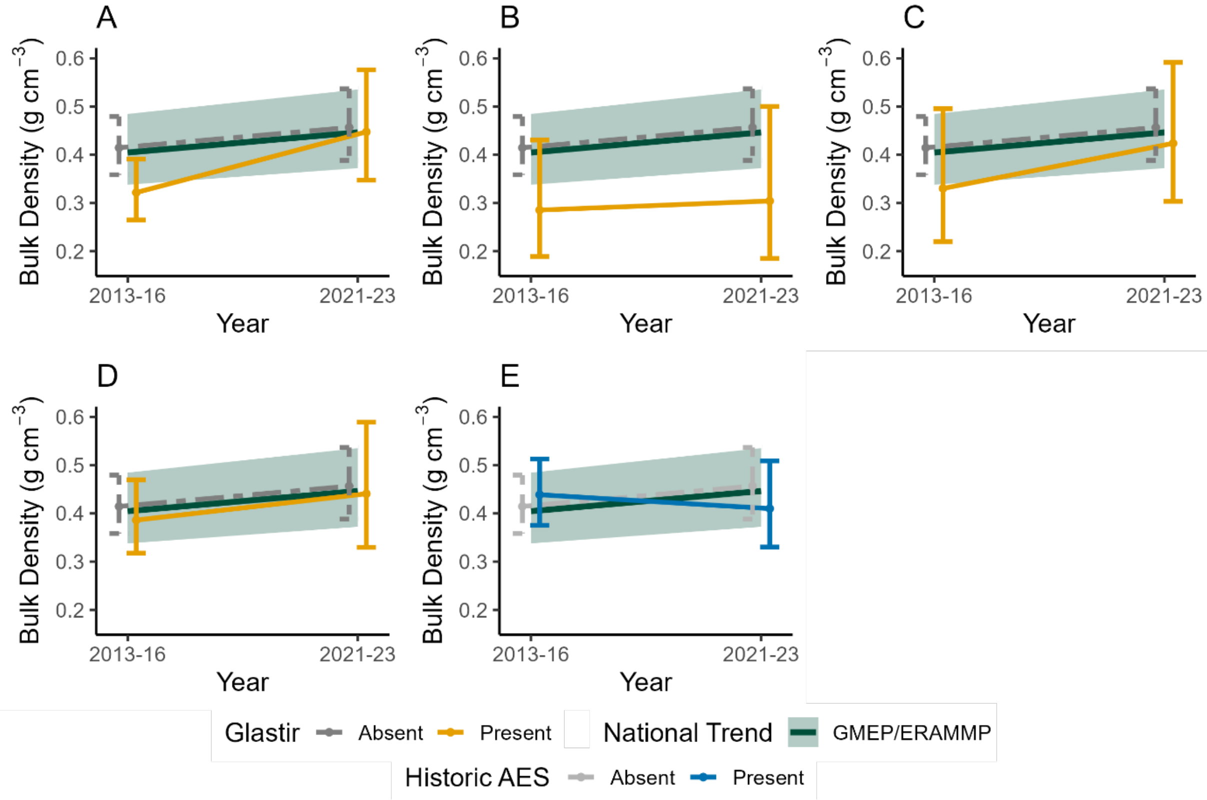

Figure 4-37 Trend in topsoil bulk density between 2013-16 and 2021-23 in Acid Grassland showing both national trend and effect of the Glastir bundles A) Glastir Habitat Management, B) Glastir Grazing Low/No Inputs Management, C) Organics, D) Commons, and E) presence in historic agri-environment schemes (AES).

4.8 Arable and Horticultural

4.8.1 National Trend

Table 4-21 Long-term and short-term trends in topsoil indicators for Arable and Horticultural land. Long-term data and trends in indicators for Arable and Horticultural land were extracted from Emmett et al. 2010 using the Countryside survey for Wales 1978 to 2007. Data analysis from this report cover the time periods 2013-16 (GMEP) and 2021-23 (ERAMMP). Models were run for each soil health indicator and Mean values, minimum and maximum confidence intervals (CI) were extracted and the mean change estimated. The p-value for the mean change in each soil health indicator is reported. No data are shown as grey boxes.

			Countryside Survey				Trend 1978-2007		2013-16			2021-23			Trend 2016-2022	
Asset class	Habitat	Indicator	1978	1990	1998	2007	Mean change	P value	Mean	min CI	max CI	Mean	min CI	max CI	Mean change	P value
Enclosed Farmland	Arable and Horticulture	Carbon (g/kg, from organic matter)	38.5			34.9	-3.6	>0.05	38.9	34.4	44.2	35.9	31.7	40.6	-3.1	0.003
		pH in water	5.00			6.48	1.48	>0.05	6.17	5.89	6.46	6.29	6.03	6.55	0.12	0.432
		N (g/100g dry soil)							0.33	0.29	0.37	0.30	0.26	0.33	-0.03	0.002
		Phosphorus (Olsen P mg/kg)							23.9	18.7	30.4	28.2	22.5	35.3	4.3	0.144
		Carbon density (tC/ha)	70.8			56.0	-14.8	>0.05	55.7	51.5	60.3	58.2	54.3	62.4	2.5	0.247
		Bulk density (g/cm3)							0.99	0.92	1.07	1.09	1.02	1.17	0.10	0.005

4.8.2 Glastir Analysis

Most soil plots had no Glastir management associated with them, and no more than one action was present. In this case, it was the Glastir Arable management bundle. Between 2013-16 and 2021-23, only two sites were part of the Glastir Arable management bundle. The population was analysed but the analysis was withdrawn due to significant results resulting from two sample points only, which was statistically not robust. Note, presence in historic AES was not analysed for its effects on topsoil indicators if Glastir coverages was not suitably represented.

Table 4-22 coverage for the Glastir analysis for Arable and Horticultural land. The Glastir Arable Management bundle, and presence in historic AES schemes is shown, but was not analysed for. Glastir bundle or historic AES present (0 = no, 1 = yes), and count for combinations for each time point (2013-16 and 2021-23).

SURVEY	Arable Management	Context: Historic AES	Count
2013-16	0	0	18
2013-16	0	1	17
2013-16	1	0	1
2013-16	1	1	1
2021-23	0	0	25
2021-23	0	1	18
2021-23	1	0	2
2021-23	**1**	**1**	**1**

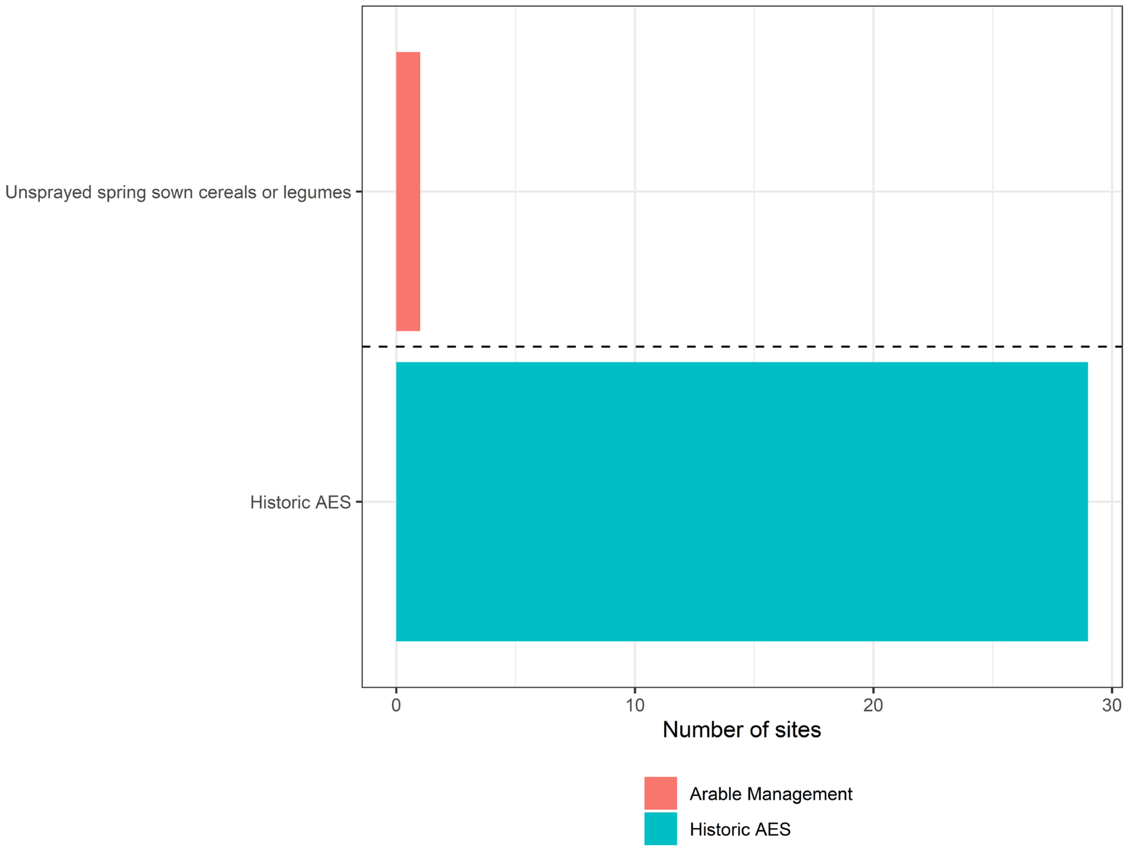

Figure 4-38 Action frequency in Glastir bundles present in Arable and Horticultural land for direct plot repeats. Only the Glastir Arable Management bundle was taken up on Arable and Horticultural land, with the action "Unsprayed spring sown serials or legumes". No Glastir analysis is reported for either.

4.9 Improved Grassland

4.9.1 National Trend

Table 4-23 Long-term and short-term trends in topsoil indicators for Improved Grassland. Long-term data and trends in indicators for Improved Grassland were extracted from Emmett et al. 2010 using the Countryside survey for Wales 1978 to 2007. Data analysis from this report cover the time periods 2013-16 (GMEP) and 2021-23 (ERAMMP). Models were run for each soil health indicator and Mean values, minimum and maximum confidence intervals (CI) were extracted and the mean change estimated. The p-value for the mean change in each soil health indicator is reported. No data are shown as grey boxes.

			Countryside survey				Trend 1978/90-2007		2013-16			2021-23			Trend 2016-2022	
Asset class	Habitat	Indicator	1978	1990	1998	2007	Mean change	P value	Mean	min CI	max CI	Mean	min CI	max CI	Mean change	P value
Enclosed Farmland	Improved grassland	Carbon (g/kg, from organic matter)	68.0		66.3	60.6	-7.4	>0.05	54.9	52.2	57.6	54.7	52.0	57.5	-0.2	0.781
		pH in water	5.36		5.74	5.94	0.58	<0.05	5.75	5.68	5.82	5.78	5.70	5.85	0.03	0.454
		N (g/100g dry soil)			0.57	0.57	0.00	>0.05	0.46	0.44	0.48	0.46	0.44	0.48	0.00	0.445
		Phosphorus (Olsen P mg/ kg)							21.4	19.4	23.6	24.7	22.1	27.6	3.3	0.005
		Carbon density (tC/ha)	72.6		69.0	68.1	-4.5	>0.05	66.9	65.3	68.6	71.9	69.9	73.9	5.0	0.000
		Bulk density (g/cm3)							0.82	0.79	0.84	0.87	0.84	0.90	0.05	0.000

4.9.2 Glastir Analysis

The Glastir impacts on Improved Grassland soil indicators were assessed using the Arable Management bundle, the Grazing Lo/No Input Management bundle, and the Organics bundle. The effect of presence in historic AES schemes was assessed too. Actions within the Habitat management advanced reversal (coastal) were also present in the dataset, but were not included in the analysis due to low representation. Given the total number of plots available for Glastir analysis in Improved Grassland, the uptake of Glastir options were very low (Table data coverage 4-24).

The Grazing Lo/No Inputs Management bundle had the largest uptake and was represented by five actions with the top three actions being Grazed permanent pasture with no, and with low inputs, and Grazed permanent pasture with low inputs and mixed grazing. The Arable Management bundle contained two actions, with the main action being “Unsprayed spring sown cereals or legumes”. The Organics bundle was represented by the action on “Glastir Organic Interventions”.

Table 4-24 Data coverage for the Glastir analysis for Improved Grassland. The Glastir Arable management bundle, Glastir Lo/No Grazing Input bundle, and the Glastir Organics bundle and presence in historic AES schemes were analysed. Glastir bundle or historic AES present (0 = no, 1 = yes), and count for combinations for each time point (2013-16 and 2021-23).

National Trend	Arable Management	Grazing Low/No Input Management	Organics	Context: Historic AES	Count
2013-16	0	0	0	0	269
2013-16	0	0	0	1	181
2013-16	0	0	1	0	4
2013-16	0	0	1	1	3
2013-16	0	1	0	0	12
2013-16	0	1	0	1	11
2013-16	0	1	1	1	2
2013-16	1	0	0	0	2
2013-16	1	0	0	1	8
2013-16	1	0	1	1	2
2021-23	0	0	0	0	127
2021-23	0	0	0	1	107
2021-23	0	0	1	0	4
2021-23	0	0	1	1	5
2021-23	0	1	0	0	11
2021-23	0	1	0	1	10
2021-23	0	1	1	1	4
2021-23	1	0	0	0	1
2021-23	1	0	0	1	2
2021-23	1	0	1	0	1
2021-23	1	0	1	1	3

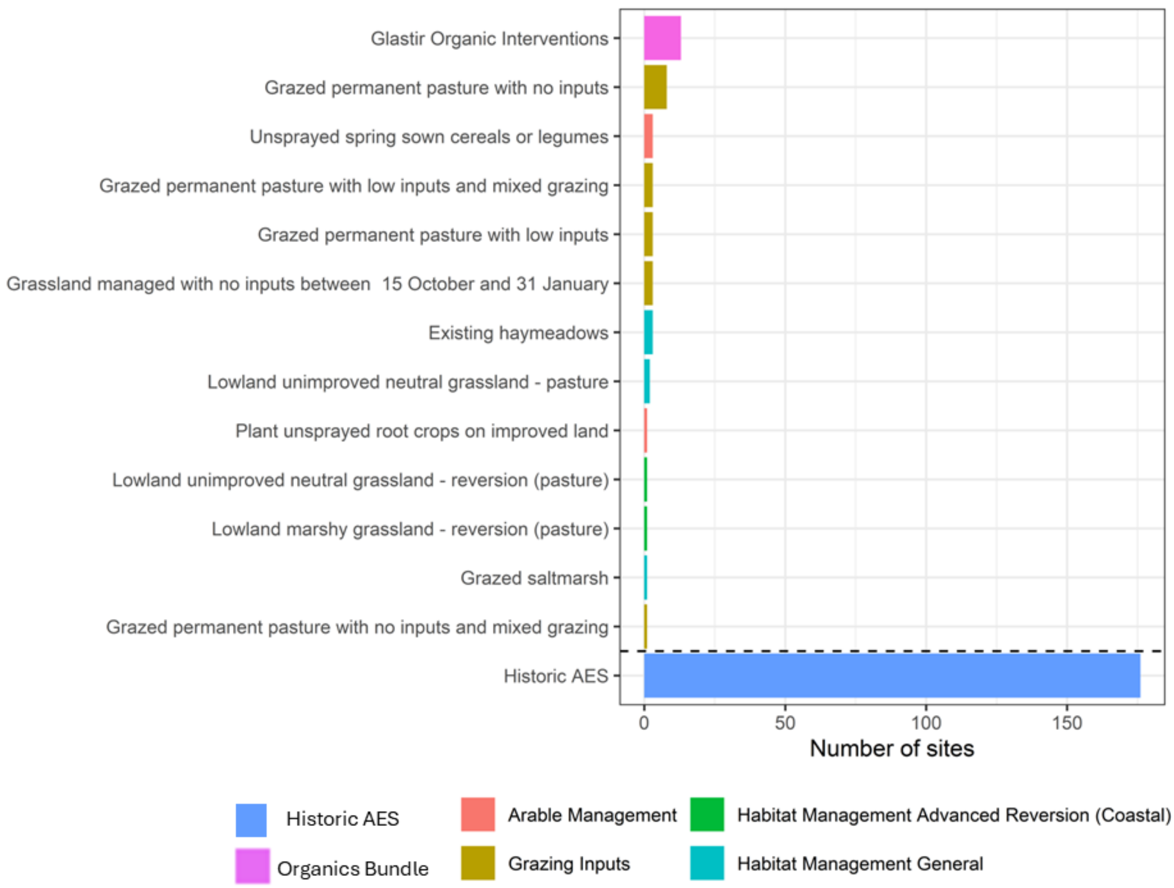

Figure 4-39 Action frequency in Glastir bundles present in Improved Grassland for resurveyed plots. The Glastir Arable Management bundle, Glastir Grazing Lo/No Inputs management bundle, Glastir Organics bundle and presence of historic AES was tested.

Table 4-25 Action frequency in Glastir bundles present in Bog in re-surveyed plots. The woodland management bundle was not analysed due to very low representation in the dataset.

		Arable Management		Grazing Lo/No Input Management		Organics		Context: Historic AES	
Habitat	Indicator	Glastir effect	P value	Glastir effect	P value	Glastir effect	P value	AES effect	P value
Improved grassland	Carbon (g/kg, from organic matter)	-1.39	0.730	-5.69	<0.01	4.71	0.210	-2.79	0.010
	pH in water	0.22	0.280	0.02	0.900	-0.09	0.580	0.05	0.440
	N (g/100g dry soil)	-0.02	0.520	0.03	0.170	0.04	0.320	-0.01	0.520
	Phosphorus (Olsen P mg/kg)	8.33	0.270	0.51	0.820	1.74	0.770	1.83	0.330
	Carbon density (tC/ha)	0.05	0.930	-1.93	0.450	2.75	0.470	-2.93	0.020
	Bulk density (g/cm3)	0.01	0.910	-0.03	0.540	-0.01	0.760	-0.01	0.740

4.9.2.1 Topsoil Carbon Concentration

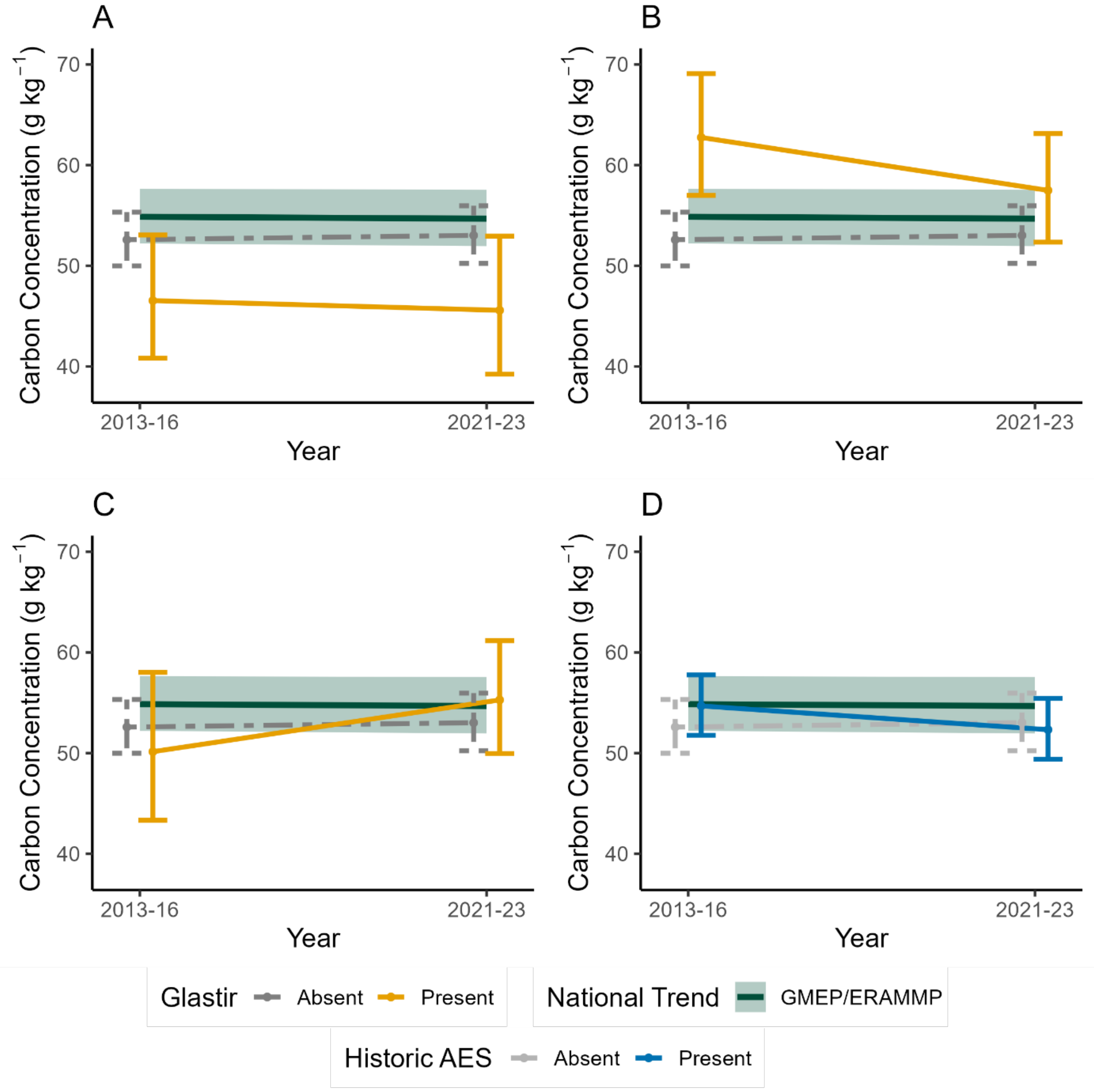

Figure 4-40 Trend in topsoil carbon concentration between 2013-16 and 2021-23 in Improved Grassland showing both national trend and effect of the Glastir bundles A) Arable Management, B) Grazing Low/No Inputs Management, C) Organics, and D) presence in historic agri-environment schemes (AES).

4.9.2.2 Topsoil pH in Water

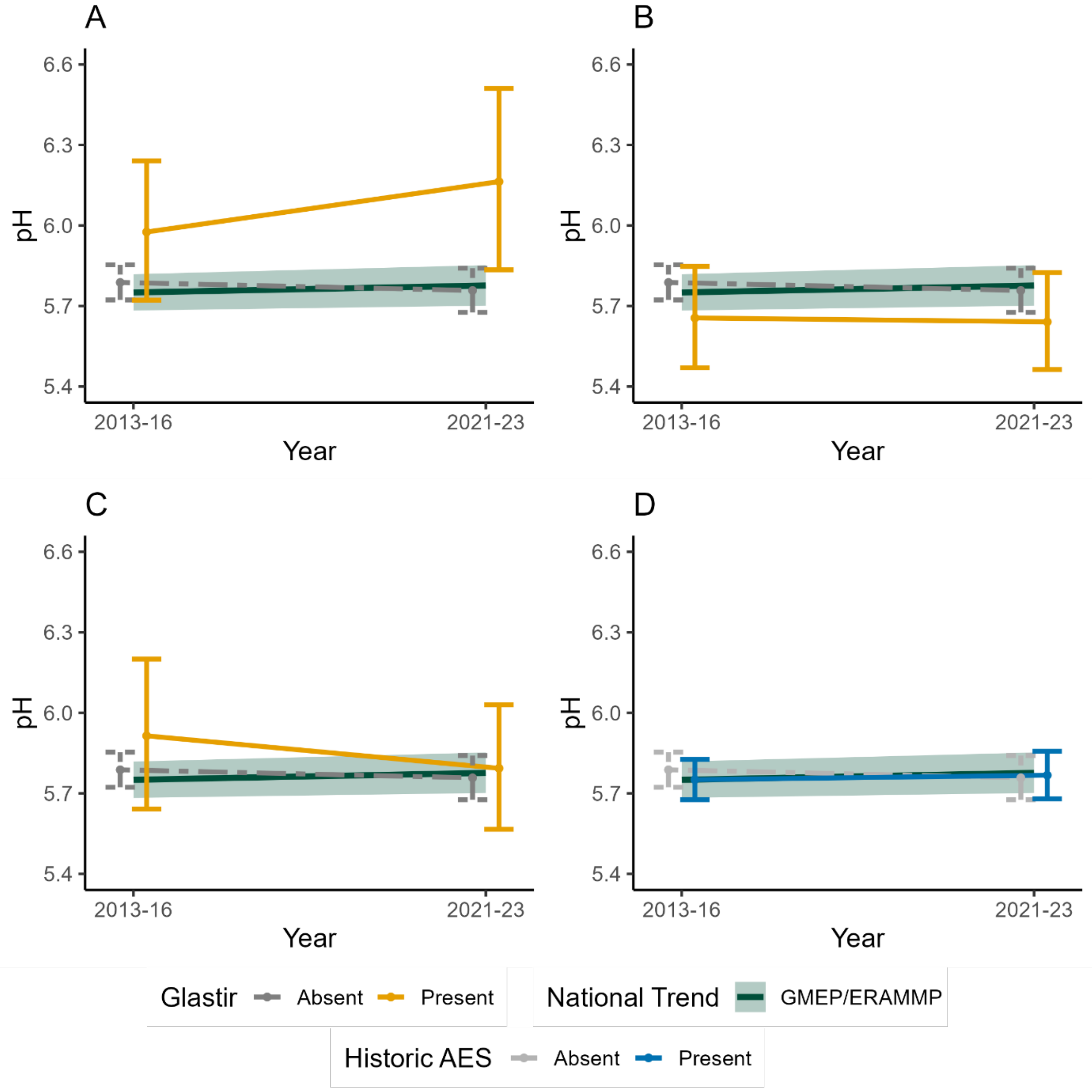

Figure 4-41 Trend in topsoil pH between 2013-16 and 2021-23 in Improved Grassland showing both national trend and effect of the Glastir bundles A) Arable Management, B) Grazing Low/No Inputs Management, C) Organics, and D) presence in historic agri-environment schemes (AES).

4.9.2.3 Topsoil Nitrogen Concentration

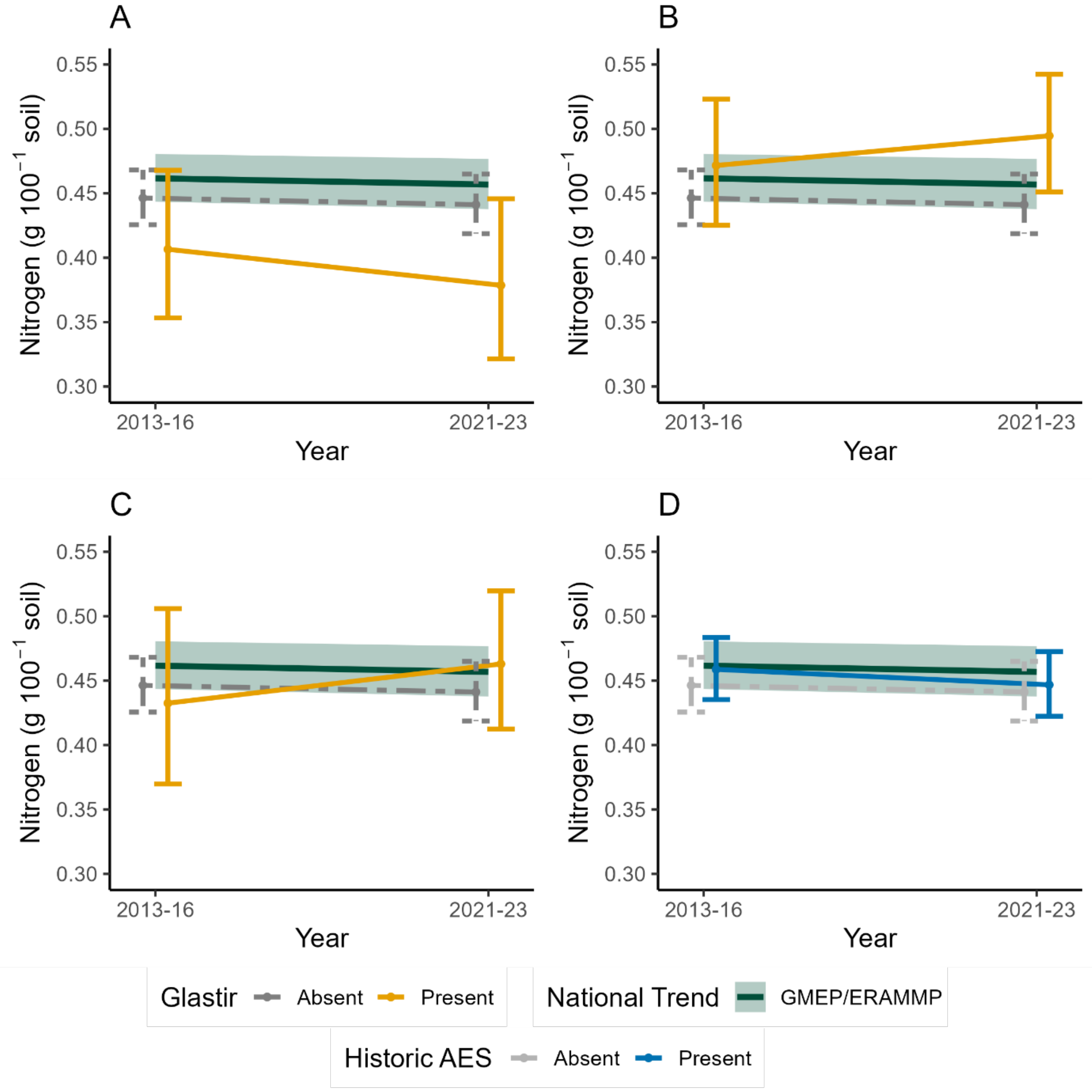

Figure 4-42 Trend in topsoil nitrogen concentration between 2013-16 and 2021-23 in Improved grassland showing both national trend and effect of the Glastir bundles A) Arable Management, B) Grazing Low/No Inputs Management, C) Organics, and D) presence in historic agri-environment schemes (AES).

4.9.2.4 Topsoil Olsen-Phosphorus

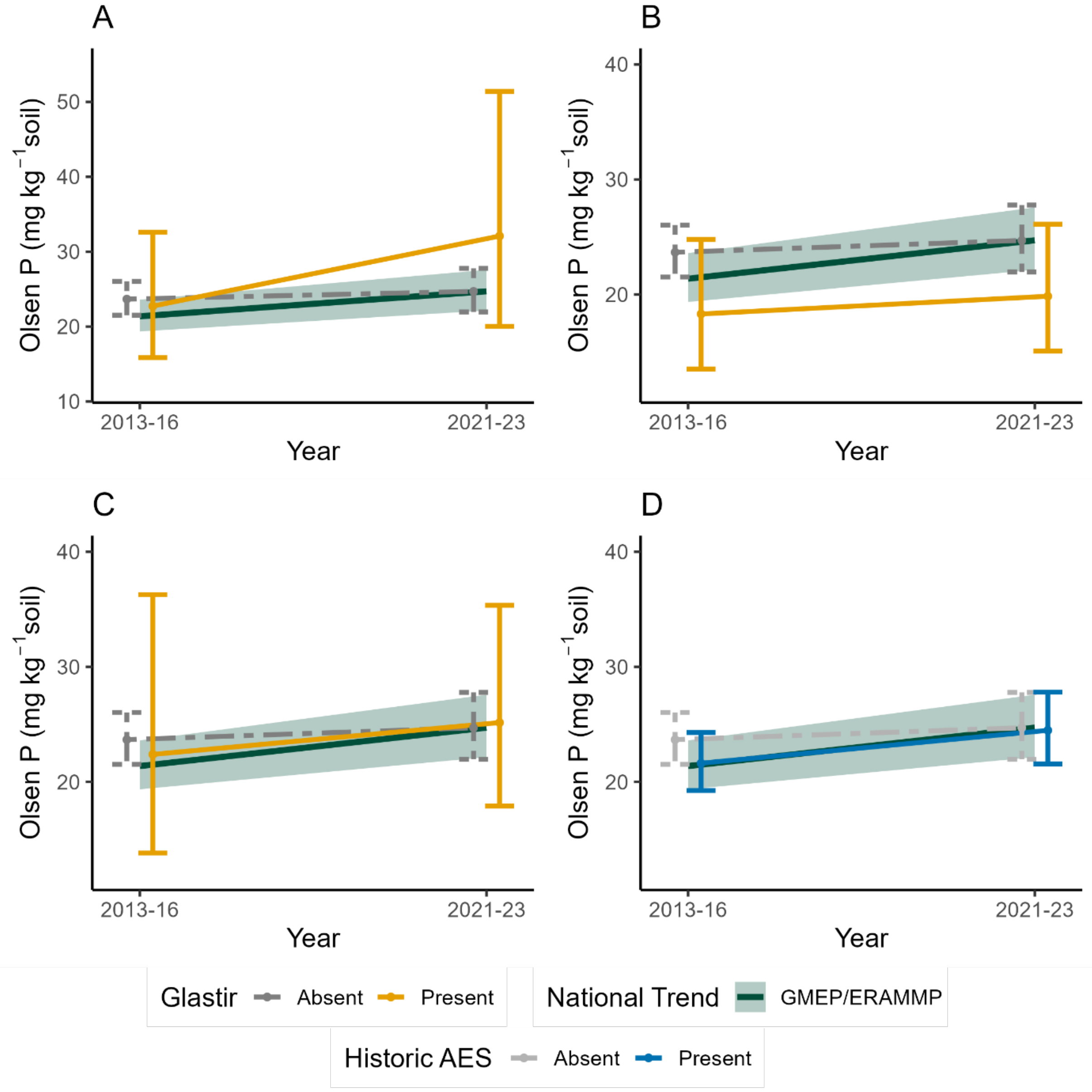

Figure 4-43 showing both national trend and effect of the Glastir bundles A) Arable Management, B) Grazing Low/No Inputs Management, C) Organics, and D) presence in historic agri-environment schemes (AES).

4.9.2.5 Topsoil Carbon Density

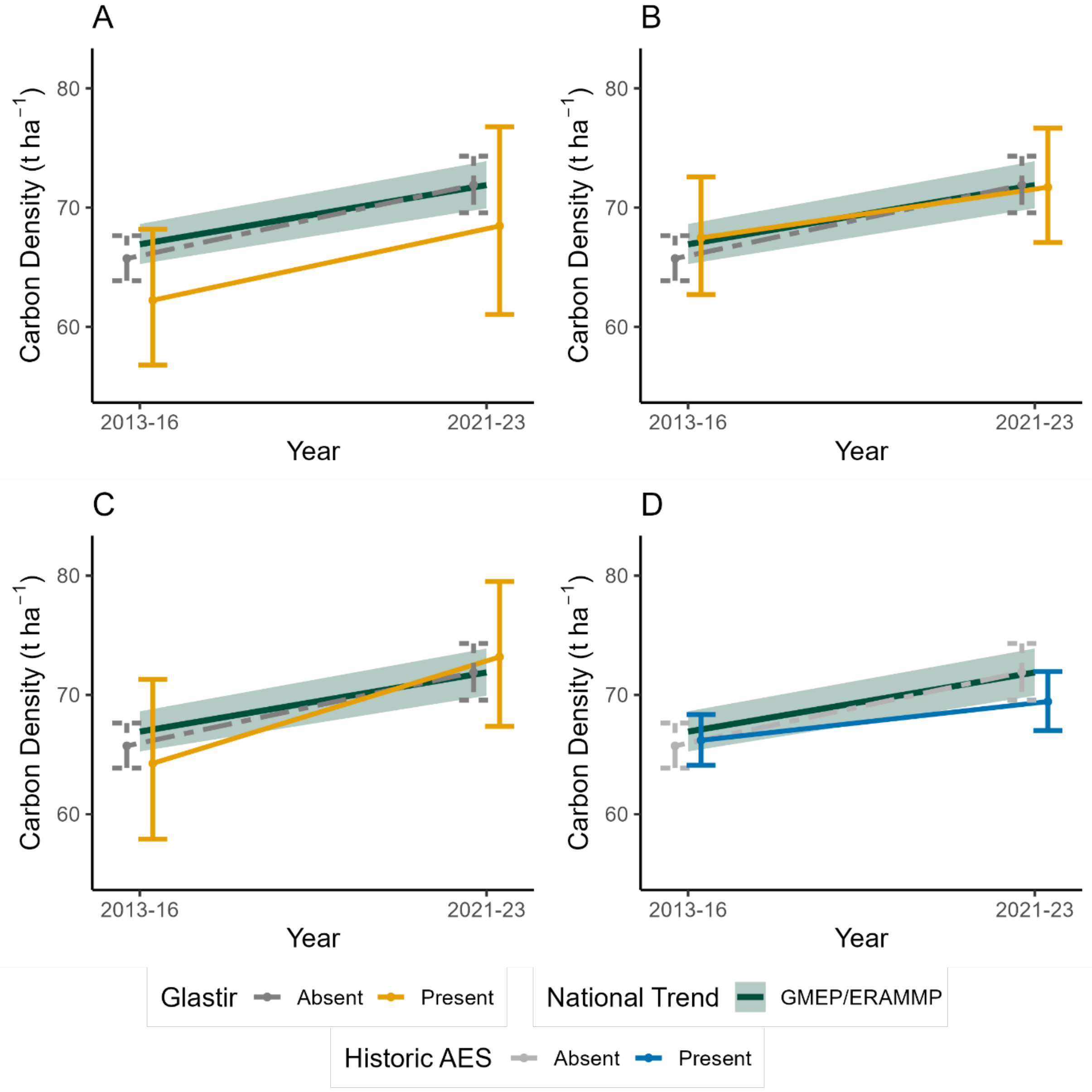

Figure 4-44 Trend in topsoil carbon density between 2013-16 and 2021-23 in Improved Grassland showing both national trend and effect of the Glastir bundles A) Arable Management, B) Grazing Low/No Inputs Management, C) Organics, and D) presence in historic agri-environment schemes (AES).

4.9.2.6 Topsoil Bulk Density

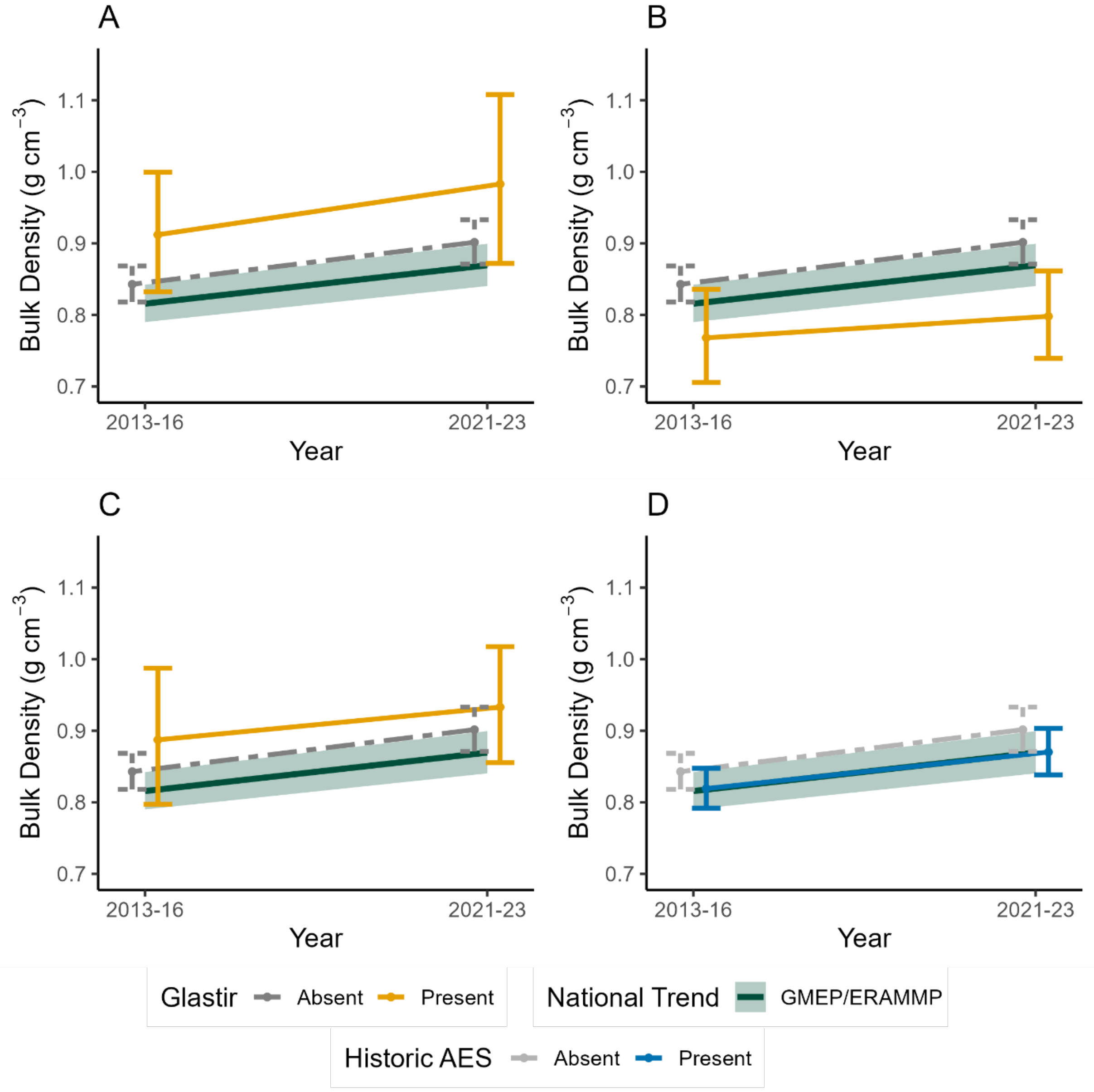

Figure 4-45 Trend in topsoil bulk density between 2013-16 and 2021-23 in Improved Grassland showing both national trend and effect of the Glastir bundles A) Arable Management, B) Grazing Low/No Inputs Management, C) Organics, and D) presence in historic agri-environment schemes (AES).

4.10 Semi-Improved Grassland

4.10.1 National Trend

Table 4-26 Long-term and short-term trends in topsoil indicators for Semi-Improved Grassland. Long-term data and trends in indicators for Neutral Grassland were extracted from Emmett et al. 2010 using the Countryside survey for Wales 1978 to 2007. Data analysis from this report cover the time periods 2013-16 (GMEP) and 2021-23 (ERAMMP). Models were run for each soil health indicator and Mean values, minimum and maximum confidence intervals (CI) were extracted and the mean change estimated. The p-value for the mean change in each soil health indicator is reported. No data are shown as grey boxes.

			Countryside survey				Trend 1978-2007		2013-16			2021-23			Trend 2016-2022	
Asset class	Habitat	Indicator	1978	1990	1998	2007	Mean change	P value	Mean	min CI	max CI	Mean	min CI	max CI	Mean change	P value
Enclosed Farmland	Semi-Improved Grassland *(neutral GL in CS)*	Carbon (g/kg, from organic matter)	53.3		57.4	62.1	8.8	>0.05	59.8	55.4	64.4	57.6	53.6	62.0	-2.1	0.200
		pH in water	5.06		5.85	5.82	0.76	<0.05	5.61	5.50	5.73	5.51	5.40	5.61	-0.11	0.103
		N (g/100g dry soil)							0.46	0.43	0.49	0.46	0.43	0.49	0.00	0.750
		Carbon density (tC/ha)	64.4		67.1	69.4	5.0	>0.05	64.7	61.5	68.1	70.6	67.3	74.0	5.8	0.001
		Bulk density (g/cm3)							0.72	0.69	0.76	0.81	0.77	0.85	0.09	0.000

4.10.2 Glastir Analysis

The impact of Glastir bundles on Semi-Improved Grassland topsoil indicators was assessed using the Habitat Management bundle, Grazing Low/No Inputs Management bundle, and the Organics bundle. The impact of the presence in historic AES schemes was assessed too. The bundles on Glastir Woodland management and Habitat Management Advanced Reversion (Coastal) were not analysed due to low representation in the soils dataset for Semi-Improved Grassland.

The Grazing Lo/No Inputs Management bundle was the largest bundle with actions covering Grazed permanent pasture with no, and with low inputs. The Habitat Management bundle was mainly represented by the actions on Existing Hay meadows. The Organics bundle was represented by the action on “Glastir Organic Interventions”.

Table 4-27 Data coverage for the Glastir analysis for Semi-Improved Grassland. The Glastir Habitat management bundle, Glastir Grazing Lo/No Input bundle, Organics bundle and presence in historic AES schemes were analysed. Glastir bundle or historic AES present (0 = no, 1 = yes), and count for combinations for each time point (2013-16 and 2021-23).

National Trend	Habitat Management	Grazing Low/No Input Management	Organics	Context: Historic AES	Count
2013-16	0	0	0	0	94
2013-16	0	0	0	1	51
2013-16	0	0	1	1	1
2013-16	0	1	0	0	3
2013-16	0	1	0	1	15
2013-16	0	1	1	1	1
2013-16	1	0	0	0	2
2013-16	1	0	0	1	3
2013-16	1	1	0	0	1
2021-23	0	0	0	0	88
2021-23	0	0	0	1	37
2021-23	0	0	1	0	2
2021-23	0	0	1	1	4
2021-23	0	1	0	0	3
2021-23	0	1	0	1	13
2021-23	0	1	1	0	2
2021-23	0	1	1	1	4
2021-23	1	0	0	0	5
2021-23	1	0	0	1	4
2021-23	1	1	0	0	1

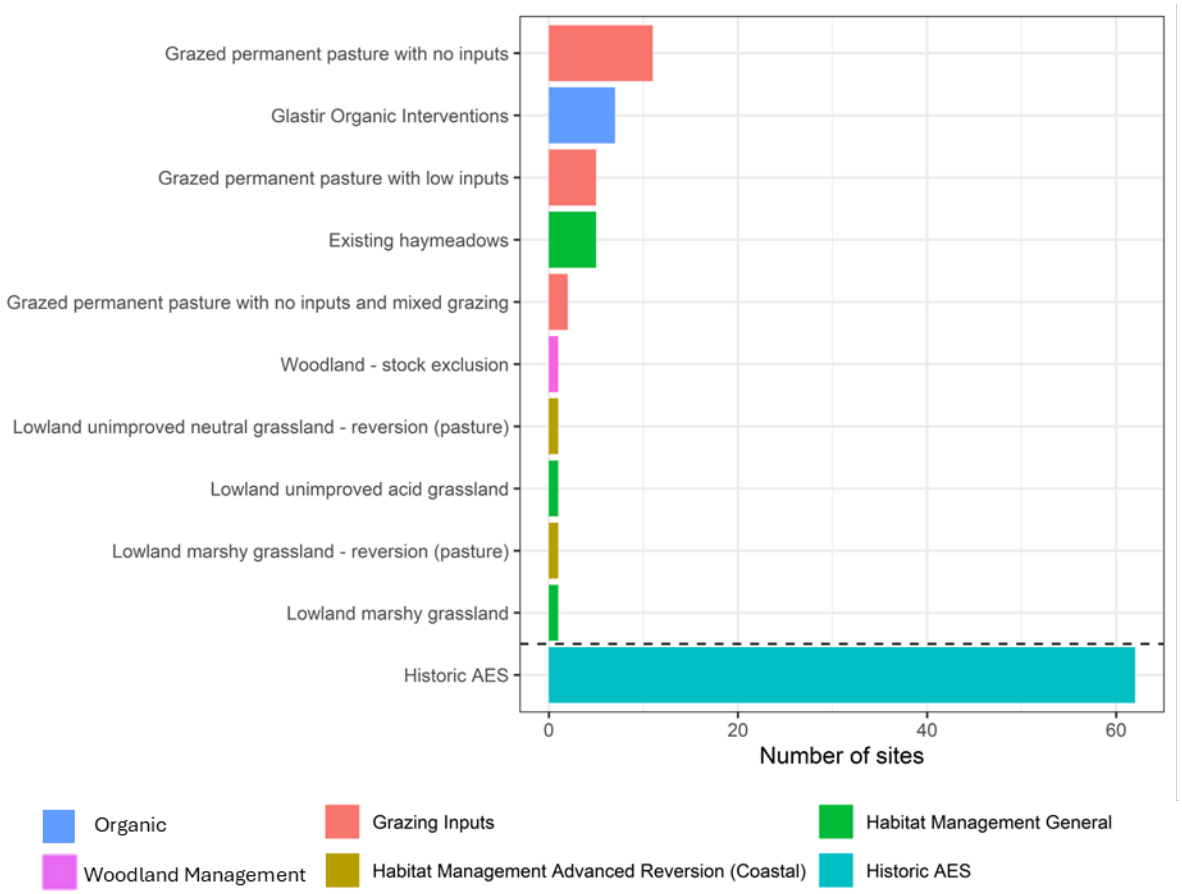

Figure 4-46 Action frequency in Glastir bundles present in Semi-Improved Grassland. The Glastir Habitat Management bundle, Glastir Grazing Lo/No Inputs management bundle, Organics bundle and presence of historic AES were analysed. The Woodland management bundle and Habitat Management Advanced Reversion (Coastal) bundle were not analysed due to low representation in the soils dataset for Semi-Improved Grassland.

Table 4-28 Glastir analysis for topsoil health indicators in Broadleaved Mixed and Yew Woodland. The models test for the effect of Glastir bundle compared to plots without the Glastir bundle on topsoil health indicators. Context effect was tested using information related to participation in historic agri-environment schemes (AES). The Glastir and Context effect was tested for 2013-16 (GMEP) compared to 2021-23 (ERAMMP). The Glastir bundle/Context effect and the associated P values are reported for each topsoil health indicator.

			Habitat Management		Grazing Low/No Input Management		Organics		Context: Historic AES	
Asset class	**Habitat**	**Indicator**	**Glastir effect**	**P value**	**Glastir effect**	**P value**	**Glastir effect**	**P value**	**AES effect**	**P value**
Enclosed Farmland	**Semi-Improved Grassland *(neutral GL in CS)***	**Carbon (g/kg, from organic matter)**	10.48	0.050	1.87	0.620	-3.49	0.670	-0.21	0.940
		pH in water	-0.30	0.150	-0.02	0.880	-0.18	0.620	0.04	0.710
		N (g/100g dry soil)	0.05	0.280	0.04	0.180	-0.03	0.700	-0.06	0.010
		Carbon density (tC/ha)	0.18	0.850	-2.04	0.570	1.92	0.820	-0.1	0.970
		Bulk density (g/cm^3)	-0.11	0.090	-0.05	0.250	0.08	0.540	0.03	0.350

4.10.2.1 Topsoil Carbon Concentration

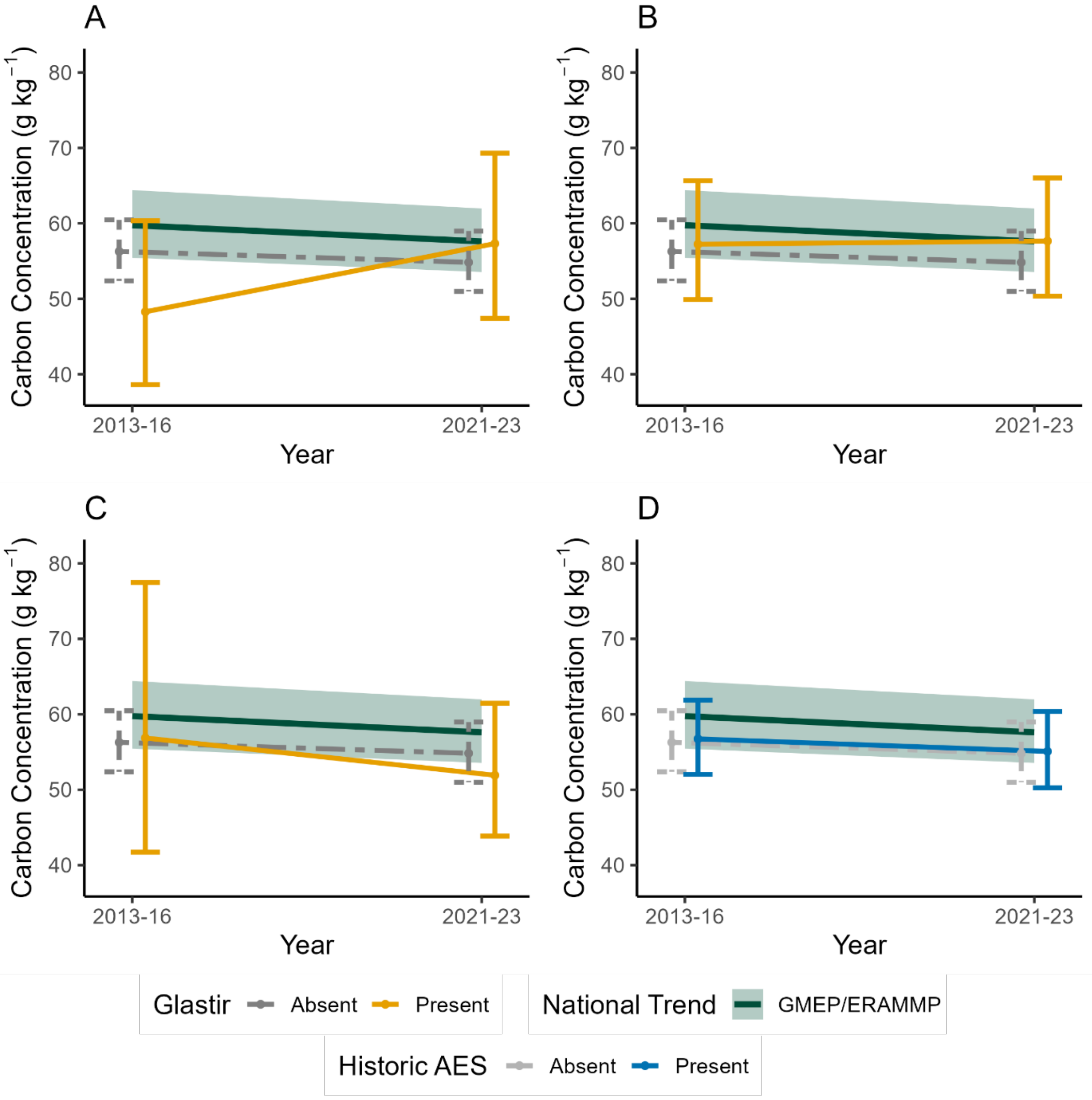

Figure 4-47 Trend in topsoil carbon concentration between 2013-16 and 2021-23 in Semi-Improved Grassland showing both national trend and effect of the Glastir bundles A) Habitat Management, B) Grazing Low/No Inputs Management, C) Organics, and D) presence in historic agri-environment schemes (AES).

4.10.2.2 Topsoil pH in Water

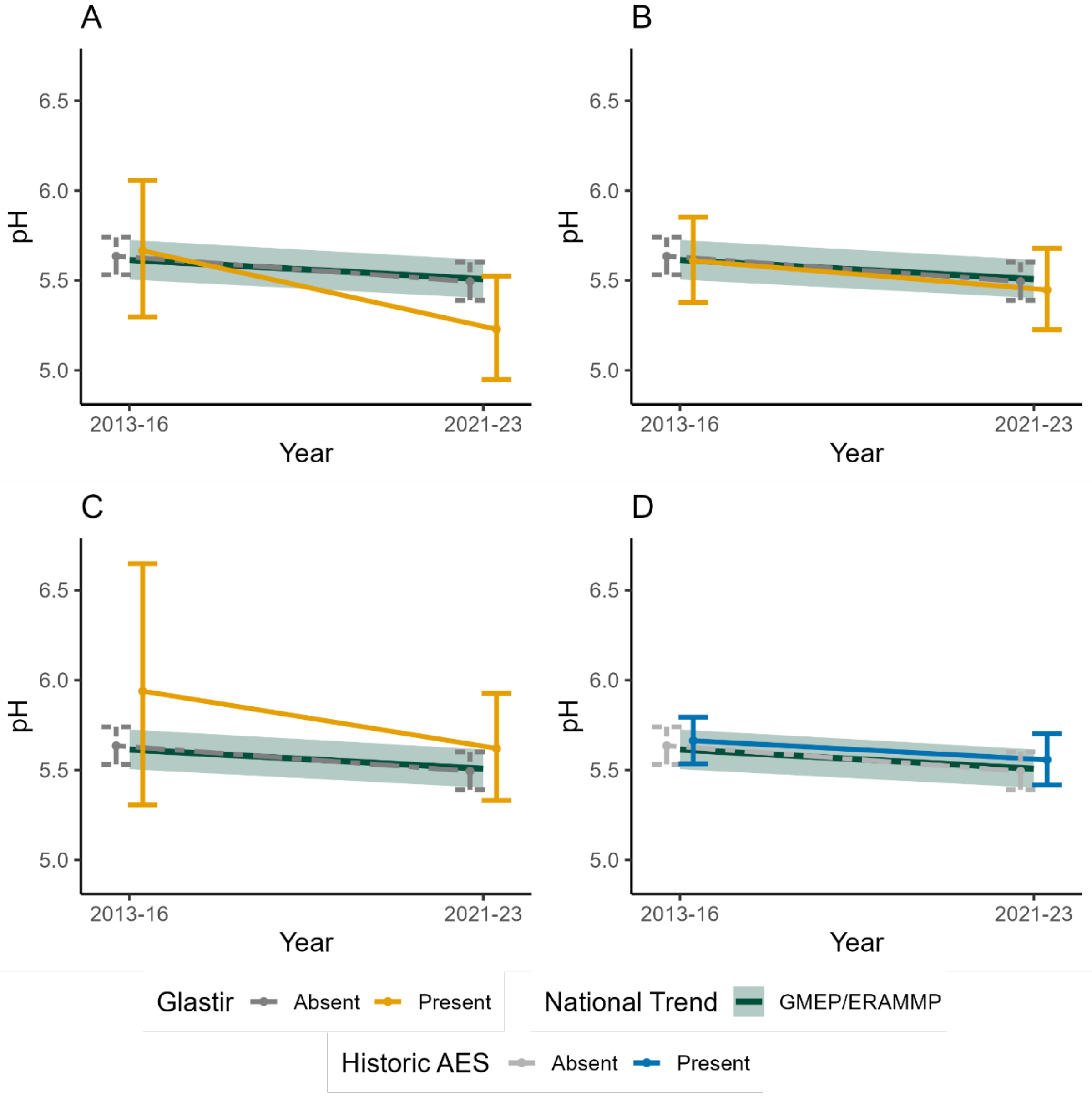

Figure 4-48 Trend in topsoil pH between 2013-16 and 2021-23 in Semi-Improved Grassland showing both national trend and effect of the Glastir bundles A) Habitat Management, B) Grazing Low/No Inputs Management, C) Organics, and D) presence in historic agri-environment schemes (AES).

4.10.2.3 Topsoil Nitrogen Concentration

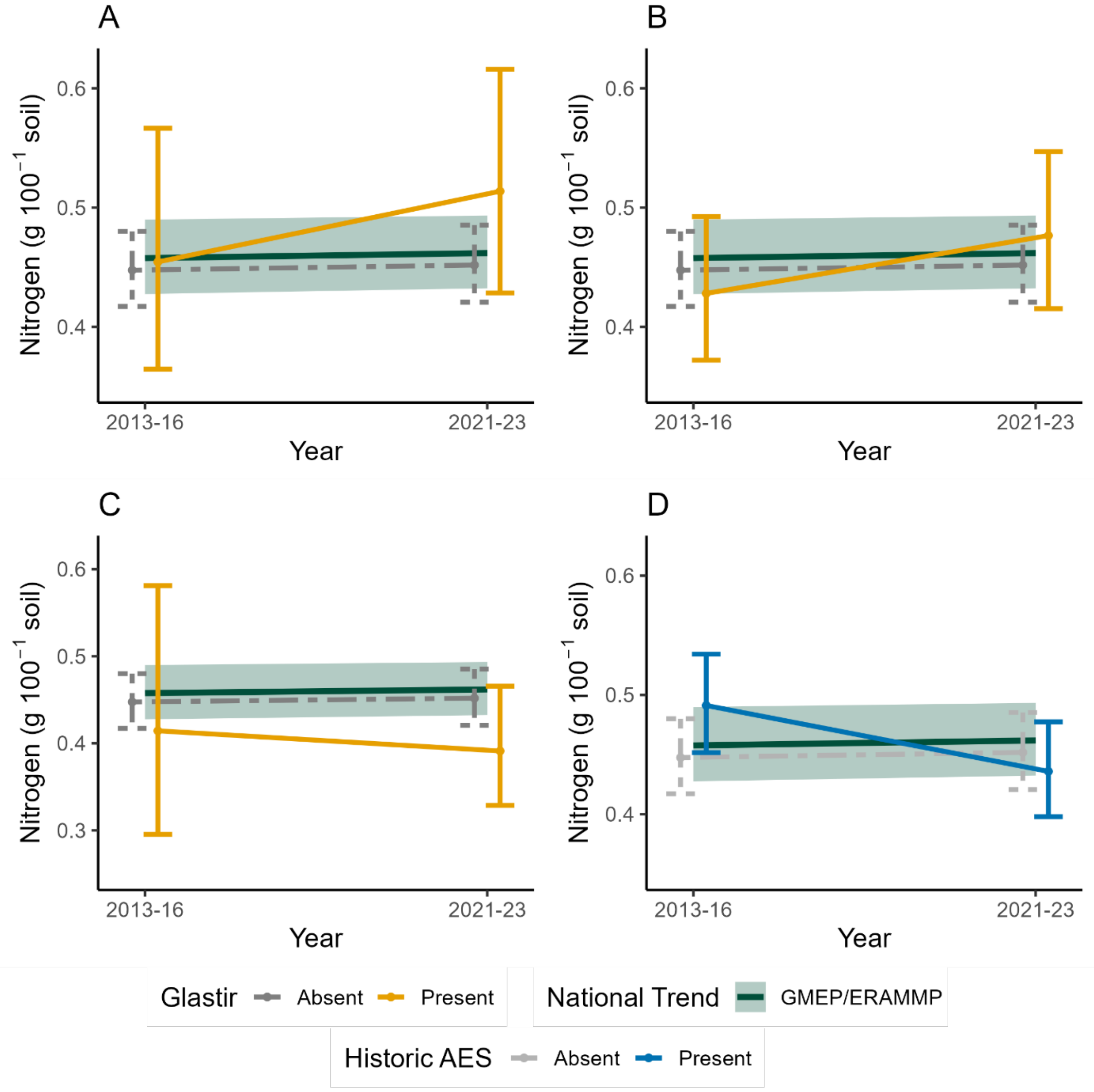

Figure 4-49 Trend in topsoil nitrogen concentration between 2013-16 and 2021-23 in Semi-Improved Grassland showing both national trend and effect of the Glastir bundles A) Habitat Management, B) Grazing Low/No Inputs Management, C) Organics, and D) presence in historic agri-environment schemes (AES).

4.10.2.4 Topsoil Carbon Density

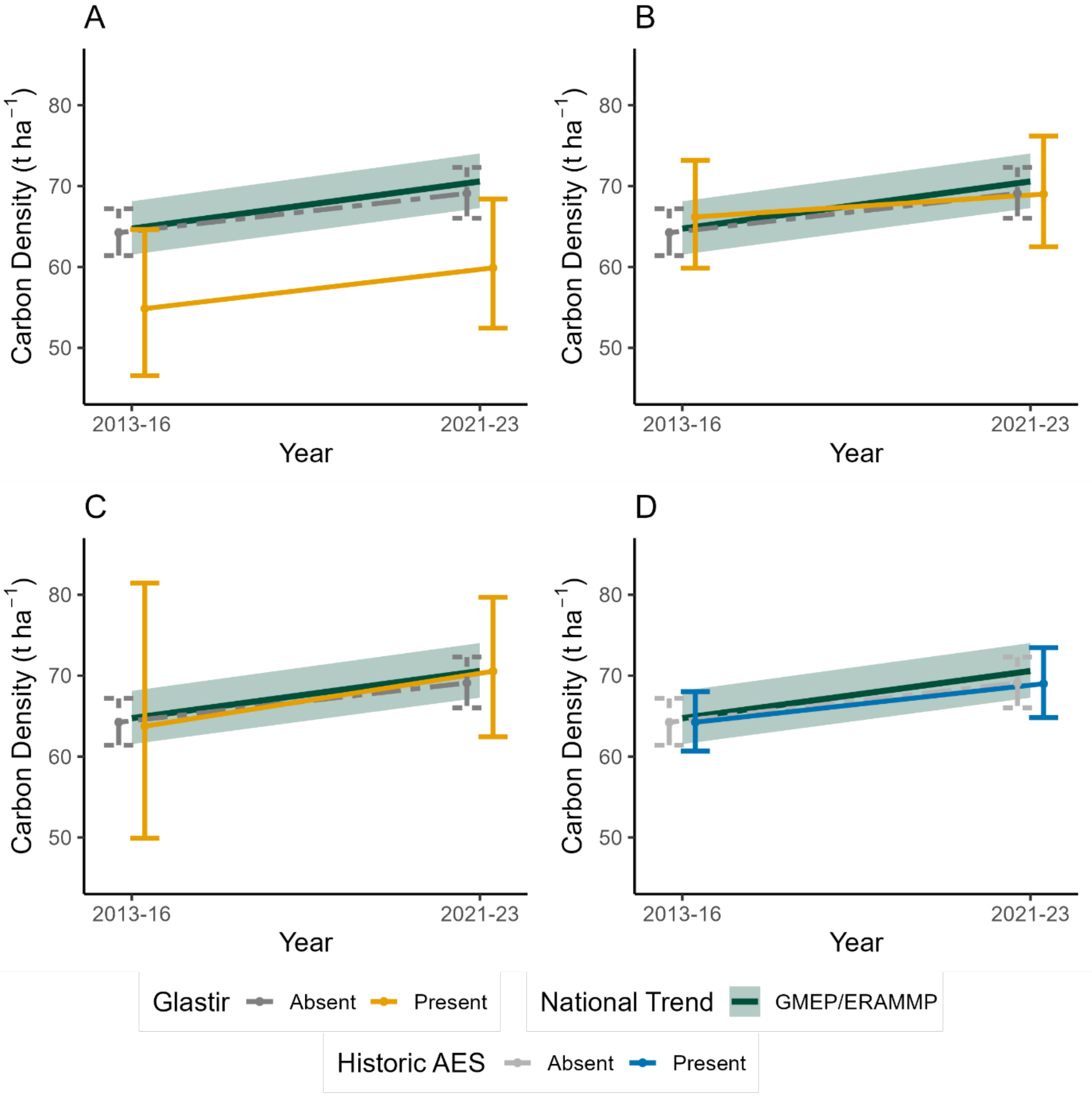

Figure 4-50 Trend in topsoil carbon density between 2013-16 and 2021-23 in Semi-Improved Grassland showing both national trend and of the Glastir bundles A) Habitat Management, B) Grazing Low/No Inputs Management, C) Organics, and D) presence in historic agri-environment schemes (AES).

4.10.2.5 Topsoil Bulk Density

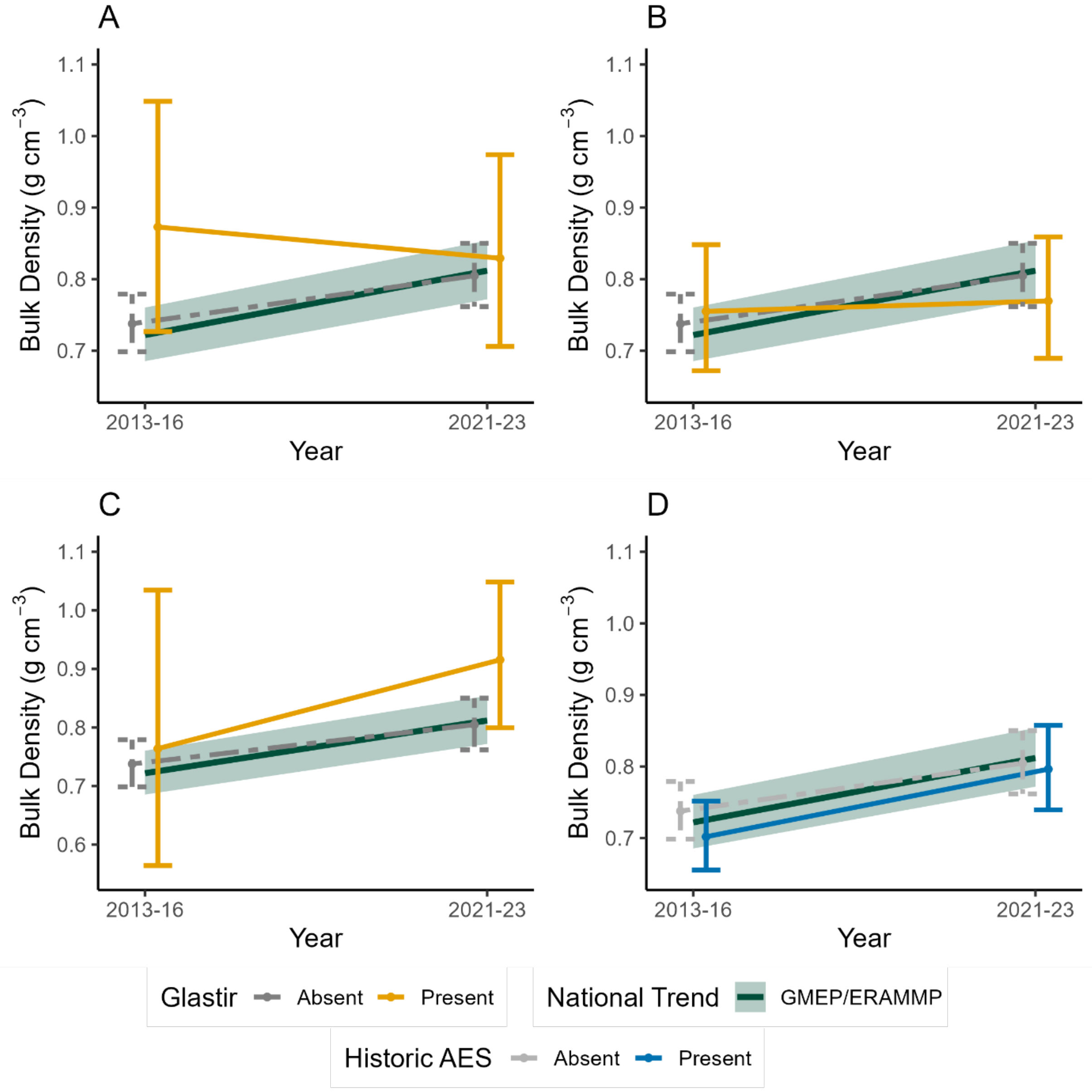

Figure 4-51 Trend in topsoil bulk density between 2013-16 and 2021-23 in Semi-Improved Grassland showing both national trend and effect of the Glastir bundles A) Habitat Management, B) Grazing Low/No Inputs Management, C) Organics, and D) presence in historic agri-environment schemes (AES).

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