Environment and Rural Affairs Monitoring & Modelling Programme (ERAMMP)

ERAMMP Technical Annex-105TA1S1: Wales National Trends and Glastir Evaluation Supplement-1: Data Analysis

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Abbreviations Used in this Report

AES	Agri-Environment Scheme
CS	Countryside Survey
CSM	Common Standards Monitoring
GMEP	Glastir Monitoring and Evaluation Programme
ITE	Institute of Terrestrial Ecology
NFS	National Field Survey
UKCEH	UK Centre for Ecology & Hydrology

Contents

1 SUMMARY

This supplement details the methods used to analyse data collected from the ERAMMP National Field Survey to create the results presented in ERAMMP Technical Annex-105TA1: Wales National Trends and Glastir Evaluation (Emmett et al, 2025). Briefly, this report covers:

- Survey square selection
- Calculation of Glastir bundle predictors
- Calculation of other covariates
- National trend models
- Glastir models

In each section we describe the overall approach taken across themes (biodiversity, soils etc) and then modifications to the overall approach which are specific to themes.

The National Field Survey (NFS) involves a large number of indicators measured across a range of ecosystems and habitats, and for Glastir analyses these are analysed in relation to specific bundles of options. We have prioritised analysis of multiple indicators by habitat and bundle, leading to many analyses conducted. To ensure a pragmatic and consistent approach across the project, where possible we have standardised approaches to ensure comparability of results and to simplify interpretation.

This supplement provides details on the analytical approach across themes and major areas of discrepancy. For specific details relating to individual analyses themes, see the relevant supplement.

2 SURVEY SQUARE SELECTION

2.1 Number of Survey Squares

A total of 300 survey squares were previously visited under the Glastir Monitoring and Evaluation Programme (GMEP). The population of squares was split into two components of 150 squares each. A Nationally Representative component (previously referred to as "Wider Wales") were selected based on a random stratified design using the ITE Land Class for stratification (Bunce et al, 2007). This ensures that sufficient squares were selected from each land class to provide a representative sample of Wales. The second component (previously referred to as "Targeted") was selected to increase the probability of capturing Glastir intervention. These squares were initially selected based on either predicted or observed Glastir uptake or payment and are not used in national trend reporting as they are biased towards areas of higher Glastir uptake.

In the ERAMMP resurvey 148 of the original 150 Wider Wales squares were revisited but only 78 of the Glastir Targeted squares, due to cost limitations (Section 3.4.4 of Emmet et al, 2025). In addition, further restrictions meant a smaller subsample of squares were assessed for birds and pollinators and not all squares contained the relevant features for some analyses (e.g. ponds or historic assets). Therefore, the number of survey squares contributing to the analysis varies across elements of the field survey. Details of the number of squares included in analyses for each theme are given in Table 2-1.

Table 2-1 Number of squares used in analysis of the GMEP and ERAMMP surveys in this report by component and theme.

Theme	Number of squares included in the GMEP survey		Number of squares included in the ERAMMP resurvey	
	Wider Wales component	Targeted component	Wider Wales component	Targeted component
Biodiversity – vegetation	150	150	146	78
Biodiversity – birds	103*	46*	103	46
Biodiversity – pollinators	104*	42*	104	42
Soils	150	150	146	78
Soil erosion	141^	111^	139	60
Freshwaters – headwaters	82	85	55	33
Freshwaters - Streamsides	80	81	64	35
Freshwaters – ponds	60	59	44	27
Historic Environment Assets	70	78	58	37
Public Rights of Way	53*	111	53*	17
Landscape metrics/HNV	150	150	148	78

*Only GMEP survey squares revisited in ERAMMP were included in data analysis for these indicators

^ Derived from Earth Observation survey

2.2 Selection of Squares for Resurvey

Resurvey of Nationally Representative squares (for National Trend analyses) was prioritised for the ERAMMP resurvey (Section 3.4.4 of Emmet et al, 2025), meaning that a selection protocol had to be developed to select the Targeted squares from the pool of 150 available for resurvey.

For the GMEP survey Targeted squares were defined as a probabilistically upweighted group of squares based on aspects of either predicted or observed Glastir uptake. The squares were selected to increase the likelihood of surveying land under Glastir and each had a specific probability of being included for survey. Because each square had a known probability of inclusion in the sample it was theoretically possible to include both components of squares in National Trend analyses by down-weighting the Targeted squares, although GMEP reporting for National Trends decided not use this approach.

For resurvey 78 Targeted squares were chosen from the pool of 150 previously visited squares based on the presence or absence of 10 key bundles of Glastir actions (Alison *et al.* 2021, ERAMMP Report 58). The squares were selected to provide a contrast of land receiving and not receiving the selected bundles to maximise the power to detect effects of Glastir bundles. Therefore, although all Targeted squares were selected in the GMEP survey due to the likelihood of observing Glastir interventions in the squares, the subselection of Targeted squares under ERAMMP mean some Targeted squares were selected for resurvey because they **did not** contain selected Glastir bundles (Alison *et al.* 2021, ERAMMP Report 58).

There are three implications of this decision that influence the analysis:

1) it is no longer possible to derive simple probabilities of inclusion for each Targeted square to enable these squares to be used in National Trend analyses;

2) the Targeted squares surveyed under ERAMMP may no longer be a representative sample of the Glastir actions used to define the initial targeting layers i.e. analyses of Glastir interventions outside of 10 selected bundles are likely to be limited by low sample size;

3) Targeted squares should no longer be interpreted as a selection of squares targeting Glastir intervention, as some squares were selected to provide a counterfactual.

These changes do not affect suitability for inclusion in Glastir analyses and so, as in GMEP reporting, the Targeted component of squares are included in analyses of Glastir but not in analyses of National Trends.

3 CALCULATION OF GLASTIR VARIABLES

3.1 Glastir Bundles

Analyses of Glastir effects focuses on bundles of options, a list of bundles used in analyses is given in Table 3-1. A full list of which options are included in which bundles is provided in this document as Appendix-1.

Table 3-1 List of bundles and the number of options in each bundle as presented in *ERAMMP Technical Annex-105TA1: Wales National Trends and Glastir Evaluation. Bundles were also subdivided however, the use of these subdivisions is dependent on the various statistical analyses across indicators.*

Bundle	Option Count
01 Grazing Inputs	6
02 Habitat Management General	38
03 Arable Management	16
04 Hedge Management	11
05 Woodland Stock Exclusion	3
06 Woodland Management	54
07 Hedge Management Advanced	2
08 Habitat Management Advanced Reversions	16
09 Habitat Management Peat	30
10 Habitat Management Heath	30
11 Wildlife Corridors	12
12 Woodland Creation	5
13 Organic	1
14 Commons	4
15 Habitat Management Advanced Birds	11
16 Birds	n/a
Bundle Subdivisions	
2A Habitat Management General Grassland	29
2B Habitat Management General Mountain; Moor and Heath	29
2C Habitat Management General Coastal	29
4A Hedge Management Reduced	5
4B Hedge Management Restoration	6
4C Hedge Management Planting	2
8A Habitat Management Advanced Reversion (Grassland)	17
8B Habitat Management Advanced Reversion (Lowland Fen Marsh and Swamp)	17
8C Habitat Management Advanced Reversion (Mountain Moor and Heath)	17
8D Habitat Management Advanced Reversion (Coastal)	17

3.2 Calculation of Glastir Predictors

For each theme (e.g. vegetation, freshwaters), Glastir uptake data were processed differently to provide measures of Glastir that were relevant to the spatial scale of measurement and the likely timescale of influence of Glastir. For responses which are integrated over large spatial areas (birds and freshwaters), it is less relevant to say whether a bundle is present or not, and more relevant to calculate the area of the relevant spatial unit (square or catchment) which has any option within a bundle present.

For example, for freshwaters we considered the presence of Glastir bundles in the upstream catchment of a headwater stream. For vegetation plots we considered only the Glastir bundles applied in a small 100m buffer around the vegetation plot.

The timeframe also varied slightly depending on theme. For example, a pollinator transect was defined as "in bundle" only if any options from that bundle were applied in the year of survey. For soils, the sample would be defined as "in bundle" if the any options from that bundle were applied in the year of survey or in the preceding years, reflecting the slower rate of response for soils compared to pollinators.

Table 3-2 gives details of the method of calculation of Glastir bundles for each theme.

Table 3-2 Method of determining relationship between field observations and Glastir bundles for each theme of analysis.

Theme	Unit of Measurement	Spatial Glastir Definition	Temporal Glastir Definition
Biodiversity – Vegetation	Vegetation plot	A plot is "in" a bundle if any actions associated with the bundle occur within a 100m radius buffer	Glastir presence in the year of survey or the preceding years (for the GMEP survey) or since the last survey (for ERAMMP resurvey). When no sample was taken in GMEP, Glastir presence is evaluated from 2015 (mean window in which baseline samples were taken in GMEP)
Biodiversity – Vegetation	Hedge	Spatial buffer of 0.5m to overlay Glastir Hedge options on linear features	Glastir presence in the year of survey or the preceding years (for the GMEP survey) or since the last survey (for ERAMMP resurvey).
Biodiversity - Birds	1km square	Glastir is summarised as the total area of land parcels within the survey square that are under an option in the focal bundle.	Glastir quantity was averaged over the five years leading up to the survey year for bundles where management effects on birds were expected to be cumulative, or in the year of the survey alone if management was expected to have a short-term effect.
Biodiversity - Pollinators	Transect section or timed observation location	A transect or timed observation location is "in" a bundle if any actions associated with the bundle occur within a 100m radius buffer	Glastir presence in the year of survey
Soils	Soil core	A plot is "in" a bundle if any actions associated with the	For the baseline sample: Glastir present for the GMEP survey if Glastir was present in the year of survey or any of the preceding years

		bundle intersect with the plot	(earliest implementation date was 2012). For subsequent soil samples, Glastir was present for that survey and sample if Glastir managements occurred since the last survey, up to and including the current year of sampling. When no baseline sample was taken, Glastir presence is evaluated from 2015 (mean window in which baseline samples were taken) for the subsequent sample to ensure a comparable timeframe was used.
Soil Erosion	1km square	N/A	N/A
Freshwaters - Headwaters	Upstream Catchment	Glastir coverage (for a specific year) is quantified for the upstream catchment as the area affected by any-and-all actions within a given bundle as a percentage of the available area within the catchment.	Glastir coverage for the baseline GMEP survey is defined as the mean coverage (in ha) across all years from the onset of Glastir in that catchment up to and including the sample year. For subsequent samples, mean coverage is calculated for all years since the previous sample, up to and including the current year of sample. When no baseline sample was taken, Glastir coverage is evaluated from 2015 (mean window in which baseline samples were taken) for the subsequent sample to ensure a comparable timeframe was used. Areas are converted to percentage of available area after temporal averaging.
Freshwater - Streamsides	Transect section (500m)	A transect is "in" a bundle if any actions associated with the bundle occurred with a 100m radius of the surveyed transect.	For the baseline sample: Glastir present for the baseline if Glastir was present in the year of survey or any of the preceding years (earliest implementation date was 2012). For subsequent soil samples, Glastir was present for that survey and sample if Glastir managements occurred since the last survey, up to and including the current year of sampling. When no baseline sample was taken, Glastir presence is evaluated from 2015 (mean window in which baseline samples were taken) for the subsequent sample to ensure a comparable timeframe was used.
Freshwaters - Ponds	Pond	A pond is "in" a bundle if any actions associated with the bundle occurred with a 100m radius of the recorded pond sample point.	For the baseline sample: Glastir present for the baseline if Glastir was present in the year of survey or any of the preceding years (earliest implementation date was 2012). For subsequent soil samples, Glastir was present for that survey and sample if Glastir managements occurred since the last survey, up to and including the current year of sampling. When

			no baseline sample was taken, Glastir presence is evaluated from 2015 (mean window in which baseline samples were taken) for the subsequent sample to ensure a comparable timeframe was used.
Historic Environmental Assets	1-km square	Glastir maximum area in-square to 2015	Glastir area to 2015
Paths	1-km square	Glastir maximum area in-square to 2015	Glastir area to 2015
Landscape Metrics/HNV	1-km square	Glastir presence of any bundle within a 1km square	Glastir presence in the year of survey or the preceding years (for the baseline sample) or since the last survey (for subsequent samples). When no baseline sample was taken, Glastir presence is evaluated from 2015 (mean window in which baseline samples were taken)

Supplementary options were excluded for Glastir calculations for birds to avoid double counting land that was managed under more than one option in a bundle (e.g. an option and a supplement).

4   CALCULATION OF OTHER COVARIATES

4.1 Historic Agri-Environment Schemes

Data were also extracted for historic agri-environment schemes (AES) Tir Cynnal and Tir Gofal. For analysis all options were combined into a single variable which determined whether an observation (e.g. plot, square or catchment) had been in an historic scheme or not. No option bundles were derived for historic schemes. Whether or not an observation was in an historic scheme was determined using the same spatial rules as presented in Table 3-2. For birds, relevant historical scheme options were included in the average annual square management totals, where they were in place in relevant years.

4.2 Background Habitat Area

For birds, it was important to control for the background habitats for bundles, to ensure that the patterns identified were independent of any effects of land cover. This was not straightforward because the bundles were broad, encompassing options that are designed for application in multiple habitats. Hence, a control variable for the total area of suitable background habitat (on which the bundle options *could* be found in practice) was calculated. All-Wales coverage data for each bundle were used to calculate the proportions of land area featuring the bundle that fell under each broad habitat type. All ERAMMP broad habitats supporting more than 10% of a bundle's total area were then considered to be relevant background habitat. Within squares, these areas were summed, weighted by the national proportion of the habitat for the bundle (weights were adjusted to sum to one), to produce a background variable for each square and bundle.

5 NATIONAL TREND MODELS

National Trends were calculated using the Nationally Representative subset of squares only. For some themes representative historical data were also available from the Welsh Countryside Survey (CS) squares, these data were analysed in a similar way to GMEP/ERAMMP data. However, the two datasets were not combined i.e. CS data were modelled separately to data collected in GMEP and ERAMMP. This represents a change from GMEP reporting when a continuous time series from CS to GMEP was estimated. This change in modelling approach should be considered when comparing results from the GMEP report to results from this report as some estimates may have changed.

The basic form of the national trend models is below:

$$\text{Response} \sim \text{Survey} + (1|\text{Unit}) \qquad \textit{Equation 1}$$

The three components are described below:

- **Response** is the indicator selected for analysis e.g. soil carbon density in broadleaved woodlands, or the number of CSM positive plant species in acid grassland.
- **Survey** indicates the time period of survey (GMEP or ERAMMP). Regardless of which individual survey year the observation is made in it is assigned to one of the two **Survey** periods. Differences due to within-survey years are generally not accounted for due to the rolling nature of the sample (e.g. the same square was not surveyed multiple times in each survey period)
- **Unit** indicates the nesting or random effect structure required to account for the survey design. For example, multiple vegetation plots are nested within a survey square, and so survey square could be included as a random term. In addition the plot identity may be included to account for repeat visits to the same plot. The exact structure of random effects may vary between themes and indicators to account for varying survey structures and varying data quantity.

For analysis of Countryside Survey data, with more time points, models also included an autoregressive term to account for the likelihood that repeat visits over time are correlated with each other.

For **Bird** models, the national trends included two random effects: Surveyor (to account for slight differences between individual surveyor across all surveys) and ID of Square surveyed. Additionally, an offset of the total area surveyed in a square was included (based on transects buffered to 100m either side).

For **Pollinator** models, random effects were transect section ID nested within square ID (transect surveys in each square were split into 10 distinct and repeatable sections, with data recorded separately for each).

6 GLASTIR MODELS

6.1 Core Structure

The aim of these models are to evaluate the impact of Glastir bundles on the indicators of interest within each theme. All surveyed ERAMMP and GMEP squares are included in this analysis (Nationally Representative and Targeted components). As noted in Section 3 there will be some differences in how bundles are defined between themes. However, to ensure consistency in the interpretation of results, all Glastir models follow the same core structure. A consistent approach allows for Glastir effects to be interpreted similarly across themes, but we acknowledge that analysing a large number of responses in a consistent way comes with a trade-off that it is not possible to optimise models for all indicators in all themes.

The key question we seek to answer with these models is whether the change between GMEP and ERAMMP survey periods is different for observation units (plots, streams etc) depending on the presence or area of Glastir bundle intervention. For example, has soil nitrogen decreased more between GMEP and ERAMMP surveys in improved grasslands under the Grazing inputs bundle of Glastir options? By phrasing the analysis this way we can compare change under Glastir to change where Glastir is absent. This means we can separate widespread changes happening across Wales without Glastir (e.g. a general trend of decreased carbon in broadleaved woodland) to the trend where Glastir bundles are applied (e.g. an increase where reduced stock density is present).

To enable this comparison requires a model structure including a **Survey*Glastir** interaction term, this allows the change between survey periods to differ depending on whether relevant Glastir bundles are present. All models follow a core structure as follows:

$$\text{Response} \sim \text{Survey*Bundle1} + \text{Survey*Bundle2} + ... + (1|\text{Unit}) \qquad \textit{Equation 2}$$

Where **Response**, **Survey** and **Unit** are defined as in Section 5 of this supplement and **Bundle** is defined as in Section 3 of this supplement.

Importantly, not all bundles are included in each model, and each indicator and habitat specific analysis has selected a subset of relevant bundles based on ecological knowledge. In addition, this model assumes bundles are not strongly correlated, which should be a reasonable assumption (i.e. different bundles of options are unlikely to routinely co-occur).

To simplify the reporting of Glastir effects, where numbers are provided these are the difference in the change in estimated mean responses between surveys where the bundle is either present (or high) or absent (or low). Low and high values are set by each theme at appropriate values for the bundle or variable of interest. Positive values indicate a more positive change between surveys where the bundle is present (or high).

6.2 Counterfactual Definition

To distinguish the effect of Glastir bundles it is necessary to have a counterfactual (i.e. a population of sampling units where the bundles were not applied). Counterfactuals were defined for each analysis based on the relevant habitat and indicator i.e. the counterfactual for woodland stock exclusion impacts on broadleaved woodland Common Standards Monitoring (CSM) positive species counts would be vegetation plots occurring in broadleaved woodland that did not have the woodland stock exclusion bundle applied. This definition implies that the counterfactual may include sampling units under other bundles,

however if those bundles are relevant for the indicator in question then this will be accounted for by the model structure (see Equation 2).

For responses with continuous Glastir definitions (e.g. the proportion of the survey square covered by a Glastir bundle) then the counterfactual is survey units not containing the Glastir bundle, but containing the background habitat of interest.

6.3 Additional Terms

In some cases additional variables are included, most commonly a Survey*HistoricAES interaction term, where historic AES is defined as in Section 4. For soil indicators, Survey*HistoricAES was only included when at least one more bundle was present for Glastir analysis.

When modelling the effects of Glastir in **Freshwater** systems (headwaters, streamsides and ponds) a control factor for the area of influence (upstream catchment or 100m radii buffers, respectively) that was under agricultural management was used, as a proxy for land use intensity. This was calculated as the percentage of the relevant area that was enclosed farmland and was included as an interaction with survey cycle as Survey*Enclosed Farmland. Including this variable allows us to separate the effect of land use intensity from the effect of Glastir. This term was not used when modelling the effects of Glastir on Enclosed Farmland specifically, where models were weighted by the percentage cover of enclosed farmland as described below.

For **Birds**, the area of background habitat available in a square relevant to the bundle and indicator of interest was included in the models. This accounts for differences in bird responses due to available habitat area. In addition, an interaction between Survey and background habitat was also included to account for changes in background habitat between surveys. Due to the relevant background habitat varying between bundles, bird analysis was only able to test bundles one at a time, whereas for other themes all relevant bundles were tested simultaneously (Equation 2).

As for the national trends, the Bird models included two random effects: Surveyor ID and ID of Square surveyed and an offset of the total area surveyed in a square. Also as above, pollinator models included transect section ID nested within square ID as random effects (see Equation 3).

Response ~ Survey + Bundle + Bundle*Survey + Bundle_Background_Habitat + Survey*Bundle_Background_Habitat + (1|Surveyor) + (1|Square_ID) + Offset(Surveyed_Area)

Equation 3

6.4 Exceptions and notes

Almost all models follow the rules above, but in a few cases models had to be adjusted significantly to match the data collected. This is particularly the case for Historic Environmental Assets, where the response variables are measured as ordinal categories. Due to the complexity of this analysis and limited data availability all relevant Glastir options were combined into a single metric, and interaction terms between Glastir and survey period were not included.

Note that in all cases where analysis is split by habitat type, the analysis uses all observations assigned to their broad habitat at the time of survey and so analyses may observations which have moved between broad habitat types between surveys.

7 MODEL IMPLEMENTATION AND VERSION CONTROL

Almost all 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. Historic environmental asset models require an ordinal response type which is not present in glmmTMB, these models were run using the polr R function (Venables & Ripley, 2002).

All model code was version controlled using git and can be accessed via private repositories on Github with permission from Welsh Government.

In addition to the glmmTMB package, the bird analysis uses the vegan package (Oksanen *et al*, 2024) to calculate a diversity index ("Simpsons") of bird diversity across the squares included in the full analysis and then compared the diversity indices with a Wilcox Test.

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9   ADDENDIX-1: LOOKUP TABLE - GLASTIR OPTION MEMBERSHIP TO GLASTIR OPTION BUNDLES

This dataset contains the lookup between Glastir options and Glastir Option Bundles used in the ERAMMP Glastir Options analysis.

row	schemeid	bundleid	optid	opt_code
1	Glastir Advanced Management Options	Arable Management	Fallow margins	27
2	Glastir Advanced Management Options	Arable Management	Retain winter stubbles	28
3	Glastir Advanced Management Options	Arable Management	Unsprayed spring sown cereals or legumes	30
4	Glastir Advanced Management Options	Arable Management	Unsprayed spring sown cereals retaining winter stubbles	31
5	Glastir Advanced Management Options	Arable Management	Establish a wildlife cover crop on improved land	33
6	Glastir Advanced Management Options	Arable Management	Unharvested cereal headland	34
7	Glastir Advanced Management Options	Arable Management	Red clover ley	153
8	Glastir Advanced Management Options	Arable Management	Buffer zones to prevent erosion and run-off from land under arable cropping	158
9	Glastir Advanced Management Options	Arable Management	Rough grass buffer zone to prevent erosion and run-off from land under arable cropping	174
10	Glastir Advanced Management Options	Arable Management	Plant unsprayed root crops on improved land	32b
11	Glastir Advanced Management Options	Arable Management	Unfertilised and unsprayed cereal headland	34b
12	Glastir Advanced Management Options	Footpaths	Access - footpaths	413
13	Glastir Advanced Management Options	Footpaths	Access - footpaths (no dogs)	414
14	Glastir Advanced Management Options	Footpaths	Access - bridlepath/cyclepath/disabled	415
15	Glastir Advanced Management Options	Footpaths	Access - bridlepath/cyclepath/disabled (no dogs)	416
16	Glastir Advanced Management Options	Footpaths	Access - dedicate new public rights of way	417
17	Glastir Advanced Management Options	Footpaths	Access - permissive access areas	418
18	Glastir Advanced Management Options	Footpaths	Access - footpaths	500
19	Glastir Advanced Management Options	Footpaths	Access - footpaths (no dogs)	501
20	Glastir Advanced Management Options	Footpaths	Access - bridlepath/cyclepath/disabled	502
21	Glastir Advanced Management Options	Footpaths	Access - bridlepath/cyclepath/disabled (no dogs)	503
22	Glastir Advanced Management Options	Footpaths	Access - dedicate new public rights of way	504
23	Glastir Advanced Management Options	Footpaths	Access - permissive access areas	505
24	Glastir Advanced Management Options	Footpaths	Access Bridges	506
25	Glastir Advanced Management Options	Footpaths	Access Gates for Disabled People	507
26	Glastir Advanced Management Options	Footpaths	Boardwalks	508
27	Glastir Advanced Management Options	Footpaths	Boardwalks - handrail supplement	509

row	schemeid	bundleid	optid	opt_code
28	Glastir Advanced Management Options	Footpaths	Hard Surfacing Footpaths	512
29	Glastir Advanced Management Options	Footpaths	Ladder Stile	514
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