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ERAMMP Technical Annex-105TA1S10: Wales National Trends and Glastir Evaluation Supplement-10: Freshwaters

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Approved by Bridget Emmett (UKCEH)
James Skates (Welsh Government)

Abbreviations Used in this Report

AES	Agri-Environment Schemes
BBS	Breeding Bird Survey
BTO	British Trust for Ornithology
CI	Confidence Interval
DARES	Diatoms for Assessing River Ecological Status
JNCC	Joint Nature Conservation Committee
PSI	Proportion of Sediment-sensitive Invertebrates
RHS	River Habitat Survey
RICT	River Invertebrate Classification Tool
RIVPACS	River Prediction and Classification System
RSPB	Royal Society for the Protection of Birds
UKCEH	UK Centre for Ecology & Hydrology
WFD	Water Framework Directive
WHPT	Whalley Hawkes Paisley Trigg

Contents

1 SUMMARY

This annex sets out an overview of the methods and additional results associated with ERAMMP Technical Annex-105TA1: Wales National Trends and Glastir Evaluation (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 Report-50. Field handbook: Freshwater 2021 (Scarlett, et al., 2021)
- ERAMMP Report-90. Field handbook stream erosion (Scarlett & Wood, 2023)

2 HEADWATERS - CATCHMENTS

The survey of headwaters captures first or second order streams that fall within the 300 1km squares surveyed in GMEP, and the subset of 224 squares resurveyed in the ERAMMP. The selection of sites for resurvey is described in ERAMMP report 58 (Alison, et al., 2021) and summarised in ERAMMP Technical Annex-105TA1S1: Wales National Trends and Glastir Evaluation. Supplement-1: Data Analysis Methods (Jarvis et al, 2025)

In both surveys, headwaters were surveyed in each square that contained a suitable stream. In the original survey (2013-16) where squares contained multiple suitable streams, one was chosen at random and that stream was subsequently revisited. For each site one visit is conducted between April and September per survey. This is to enable co-location with other field survey components and coordination with the other aspects of the freshwater survey described in this document, and financial and logistical limitations. As such, the survey does not follow the Water Framework Directive (WFD) requirement to base classification on minimum of two samples per site per year, and as such should not be used to assess headwater status. However, the survey method can be used to determine an indicator of headwater condition via the approach otherwise used in the WFD, along with other metrics of condition. Survey methods have also remained constant over time, allowing us to report on changes in headwater condition at a national scale.

The field survey of headwaters contains three separate workflows (Figure 2-1):

- River habitat survey (RHS) conducted over a 500m section of stream
- Macroinvertebrate survey over a 10-15m reach at the centre of the RHS section
- Diatom survey following the DARES method at the same location as the macroinvertebrate survey.

A full description of the field survey methods used is provided in Scarlett, et al. (2021) & Scarlett & Wood (2023). Field survey and data collection was done by UKCEH. Data cleaning and variable calculation is performed by APEM for the macroinvertebrate survey and Bowburn Consultancy for the diatom survey. In both cases this included taxonomic identification and calculation of derived variables using contextual information provided from the environmental data record collected in the field, including stream chemistry measurements. Subsequent data cleaning and integrity checks are performed by UKCEH. In all cases, variables were calculated using consistent methods for all surveyed time periods. In some cases this includes the re-calculation of variables previously published from the 2013-16 GMEP field survey where methods have evolved, and the calculation of new variables from the previous dataset where needed.

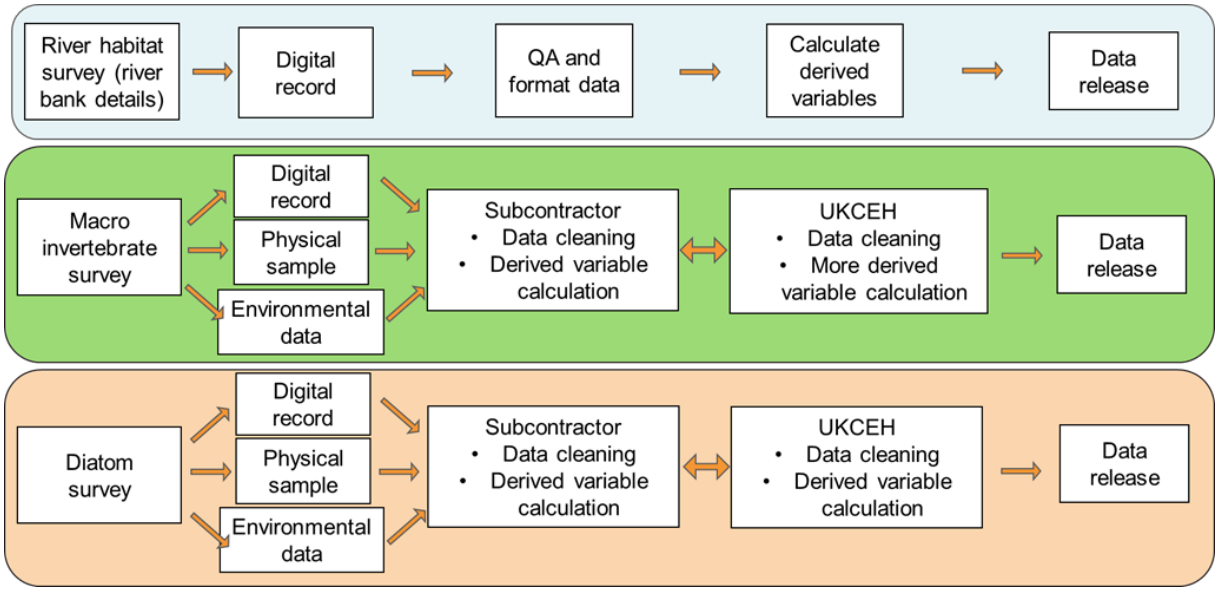

Figure 2-1 Data collection and processing pathways for data collected within the headwater monitoring in the ERAMMP and GMEP monitoring programs.

2.1 Dataset Overview

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, Barr, Clarke, Howard, & Scott, 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 (Nationally representative sites) were revisited but only 78 of the Targeted squares (which targeted areas with high Glastir Option uptake), due to cost limitations. However, not all squares contain relevant features for headwaters. Additional information can be found in the ERAMMP Technical Annex-105TA1S1: Wales National Trends and Glastir Evaluation. Supplement-1: Data Analysis Methods (Jarvis et al., 2025).

Raw data coverage across all years of the first survey (GMEP, 2013-16) and recent resurvey (ERAMMP, 2021-23) is provided in Table 2-1. Each site is surveyed once per survey cycle. Data coverage can differ across aspects of the headwater survey due to:

- Incomplete landowner permissions for the River Habitat Survey
- Dry streams
- Low water quality or high sediment levels (particularly impactful for stream chemistry and diatom species samples)
- Inaccessible areas or changes in accessibility in the field
- Non-viable biological sample

Table 2-1 Squares surveyed during GMEP and ERAMMP National Field Survey of headwaters.

Data collection	GMEP (2013-16)				ERAMMP (2021-23)		
	2013	2014	2015	2016	2021	2022	2023
River Habitat Survey	35	51	36	32	59	3	37
Macro invertebrates	36	56	38	38	55	2	33
Macroinvertebrate environmental data	36	58	38	38	55	2	34
Diatoms	29	51	37	33	54	2	29
Diatom environmental data	35	58	38	36	54	2	29

For all survey sites, the upstream catchment is defined as the area upstream of the macroinvertebrate and diatom sampling centre-points, which corresponds to the centre of the River Habitat Survey area. 75% of monitored upstream catchments are smaller than 150 ha, up to a maximum area or 760 ha. A comparison of catchment areas from the 2013-16 survey and the 2021-23 survey shows that the resurvey has captured the full range of catchment sizes and overall distribution of catchment areas (Figure 2-2)

As with all survey locations in ERAMMP, exact survey locations are not disclosed. However, the coverage of survey sites within WFD river catchments for both surveys (2013-16 and 2021-23) is provided in Figure 2-3.

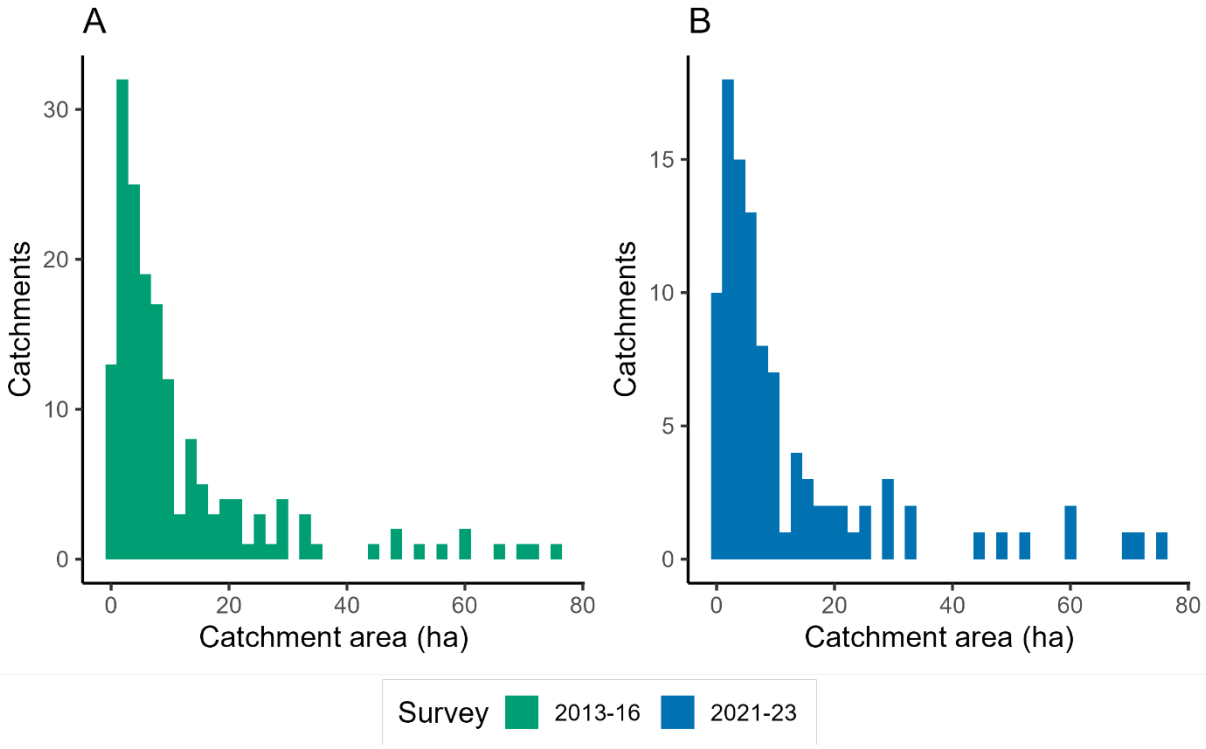

Figure 2-2 Estimated catchment areas across all surveyed sites from the GMEP (2013-16) and ERAMMP National Field Surveys (2021-23).

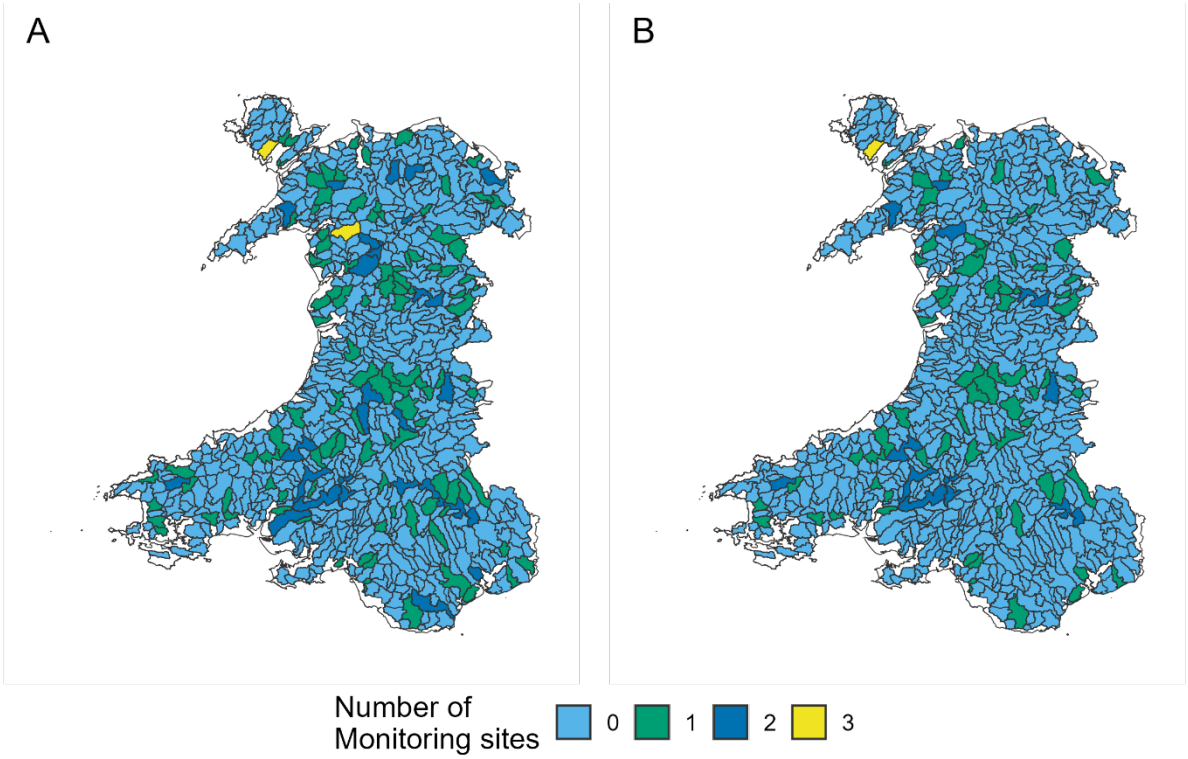

Figure 2-3 Number of sampled 1 km^2 squares within Water Framework Directive (WFD) River Waterbody Catchments Cycle 3 where A) is sample coverage during GMEP (2013-16) and B) is sample coverage during ERAMMP (2021-23). Contains Natural Resources Wales information © Natural Resources Wales and Database Right. All rights Reserved. Contains Ordnance Survey Data. Ordnance Survey Licence number AC0000849444. Crown Copyright and Database Right.

2.2 Data Quality Assurance

All data used in these analyses have been subject to quality assurance. This includes:

- Manual inspection and verification of reported survey locations against historic reports and photographs.
- Inspection of all raw data and derived variables against known ecological limits and historic reporting
- Confirmation of data continuity and integrity across survey strands
- Independent quality assurance of taxonomic ID carried out by subcontractors.
- Inspection of taxonomic data for errors and synonyms

In addition, surveyor training and procedures are reviewed on an annual basis. Reporting methods and methods used in the derivation of all reporting variables are reviewed for each reporting cycle. All changes made to the data are recorded to maintain a robust audit trail.

2.3 Derived Indicators

The following indicators and metrics are reported on in ERAMMP Technical Annex-105TA1: Wales National Trends and Glastir Evaluation (Emmett et al., 2025) using the headwaters dataset for status and change in condition over both survey periods:

- Incidence of dry streams
- Presence of invasive species

- Abundance of invasive species
- Macroinvertebrate Index of Stream Health ASPT – Observed/ Expected ratio, also known as Whalley Hawkes Paisley Trigg (WHPT) score for the average score per taxa scoring taxa (ASPT)
- Macroinvertebrate Index of Stream Health NTAXA - Observed/ Expected ratio, also known as Whalley Hawkes Paisley Trigg (WHPT) score for the number of scoring taxa (NTAXA)
- Macroinvertebrate Index of Stream Health - also known as WHPT overall category
- The Macroinvertebrate Sediment Index - Observed/ Expected ratio, also known as The Proportion of Sediment-sensitive Invertebrates (PSI).

A description of the meaning of these indicators in a stream health context is provided in Section 6.1.2 of ERAMMP Report-105TA1: Wales National Trends and Glastir Evaluation (Emmett et al., 2025), however some additional context is provided below.

2.3.1.1 Dry Streams

Streams reported as dry were dry at the time of the fields survey visit. This is not an uncommon state for a headwater stream and is not in and of itself a cause for concern. However, trends in the frequency of dry streams may be indicative of changing pressures on headwater systems, with the potential to substantially impact the system.

2.3.1.2 Invasive species indicators

The species present in stream samples were checked against a list of freshwater invasive species of concern to Wales (NBN Atlas, 2019) which identified 162 aquatic alien species from the 348 invasive non-native species currently of most interest to Wales and taxa relevant to UK Biodiversity targets B6 (Harrower et al., 2023). The level of Invasive risk category was derived from the impact classification working paper (WFD-UKTAG, 2015).

The metrics of invasive macroinvertebrate species presence and abundance calculated for headwaters were:

- Invasive species richness (%): the mean percentage of taxa in each sample that were invasive across samples
- Invaded streams (%): the percentage of streams that contained at least one invasive invertebrate taxa
- Mean invasive species abundance (% individuals): the mean percentage of individuals in each sample that were invasive, across samples
- Taxa site presence: total count of streams where each specific invasive taxon is present
- Taxa abundance: total abundance across all the streams where each taxon is present

2.3.1.3 Macro-invertebrate derived indices

For the macroinvertebrate indices, where Observed/Expected scores were used, the observed score was derived by APEM. Expected scores were calculated by UKCEH. Expected WHPT-ASPT, WHPT-NTAXA, and PSI scores and classification for samples were calculated using River Invertebrate Clasification Tool (RICT) v3.1.7 (Muyeba, Foster, and Loveday, 2024).

Input data for the classification tool consists of time invariant variables characterising the site's geological and fluvial setting. The required variables of sample National Grid Reference, altitude, distance from source, slope and mean flow, were using a GIS software following the approach described in (Dawson et al., 2002). Water chemistry values for site alkalinity were taken from the 2013-2016 survey data, values for new sample sites were obtained in from recent laboratory analysis of water samples analysed for the diatom

metrics. Time variant variables of water depth, channel width, substrate composition are also required for the calculation and were recorded at each sampling occasion. Site representative values were derived by averaging values from the two sampling occasions.

Sample WHPT-ASPT and WHPT-NTAXA values were input under the appropriate season with an assumed sample bias of 1.68 (Environment Agency, 2015). Biotic data was recorded to taxonomic level 2 abundance-related values for distinct families by APEM. Expected family WHPT ASPT, WHPT NTAXA and Species level PSI scores were compared with observed values to calculate the observed/expected ratio.

The RICT (River Invertebrate Classification Tool) outputs the probability of a sample belonging to each possible condition classification, using the latest WFD classification class boundaries (High, Good, Moderate, Poor, Bad) set by EU member states (WFD-UKTAG, 2023). Each site was assigned the condition category with the highest probability.

Table 2-2 Status boundaries for condition of headwater streams, derived from Whalley Hawkes Paisley Trigg (WHPT) score for the number of scoring taxa (NTAXA) observed over expected (O/E) and Whalley Hawkes Paisley Trigg (WHPT) score for the average score per taxon.

Status boundary	WHPT NTAXA O/E	WHPT ASPT O/E
High/Good	0.80	0.97
Good/Moderate	0.68	0.86
Moderate/Poor	0.56	0.72
Poor/Bad	0.47	0.59

Caution should be applied using the RICT on headwater streams, due to the under representation of headwater streams in the River Prediction and Classification System (RIVPACS) reference dataset that the RICT draws on. A consequence of this is uncertainty as to the suitability of the reference site as a reliable comparison. The representation of input sites in the model reference population is summarised in the model output as a suitability code. Results with a suitability code of four or greater would be deemed unreliable for the purposes of WFD classification (WFD-UKTAG, 2023) The majority of streams in the Wider Wales survey squares were found to have a suitable reference site in the model, however 18 did not. The number sites with unsuitable reference site available in the model increases considerably for site in the Targeted survey squares.

Table 2-3 Count of suitability codes for reference sites in the RICT model as comparators to streams in the Wider Wales survey squares and Targeted survey squares.

Suitability Code	Count of Suitability Code WW	Count of Suitability Code TG
1	49	40
2	7	7
3	6	7
4	9	8
5	9	24

2.4 Habitat Classification

Habitat coverage across headwater catchments was assessed using the UKCEH Land Cover Map. Habitat cover was assessed for 2013-16 using a 2010 product (Levy, et al., 2024) and for 2021-23 using a 2021 product (Marston, Rowland, O'Neil, & Morton, 2022) derived using the same methods. The classifications provided by Land Cover Map were aggregated to provide greater compatibility with the broad habitat classification and asset classes used elsewhere within ERAMMP reporting, as described in Table 2-4. Aggregated broad habitats were subsequently used in all assessments of catchment habitat cover. For all analysis where habitat cover was considered, we used the habitat cover at the beginning of the survey period corresponding to the 2010 Land Cover Map.

Table 2-4 Mapped corresponding habitat classifications across the Land Cover Map classification scheme and the Broad Habitat classification used in this report and the resulting aggregate habitat classifications taken from Land Cover Map classes and used in this report.

LCM class	Broad habitat	Aggregated Broad Habitats
Broadleaved woodland	'Broadleaved, mixed and yew woodland'	Woodland
'Coniferous woodland'	'Coniferous woodland'	Woodland
'Arable and horticulture'	'Arable and horticulture'	Enclosed Farmland
'Improved grassland'	'Improved grassland'	Enclosed Farmland
'Neutral grassland'	'Neutral grassland'	Semi-natural grassland and Fen
'Calcareous grassland'	'Calcareous grassland'	Semi-natural grassland and Fen
Acid grassland	'Acid grassland'	Semi-natural grassland and Fen
'Fen, marsh and swamp'	'Fen, marsh and swamp'	Semi-natural grassland and Fen
Heather	'Dwarf shrub heath'	Mountain, moor and heath
Heather grassland		
'Bog'	'Bog'	Mountain, moor and heath
'Inland rock'	'Inland rock'	Mountain, moor and heath
Saltwater	Saltwater	Saltwater
Freshwater	Freshwater	Freshwater
'Supra-littoral rock'	'Supra-littoral rock'	Coastal
'Supra-littoral sediment'	'Supra-littoral sediment'	Coastal
'Littoral rock'	'Littoral rock'	Coastal
Littoral sediment	'Littoral sediment'	Coastal
Saltmarsh		
Urban	'Built-up areas and gardens'	'Built-up areas and gardens'
Suburban		

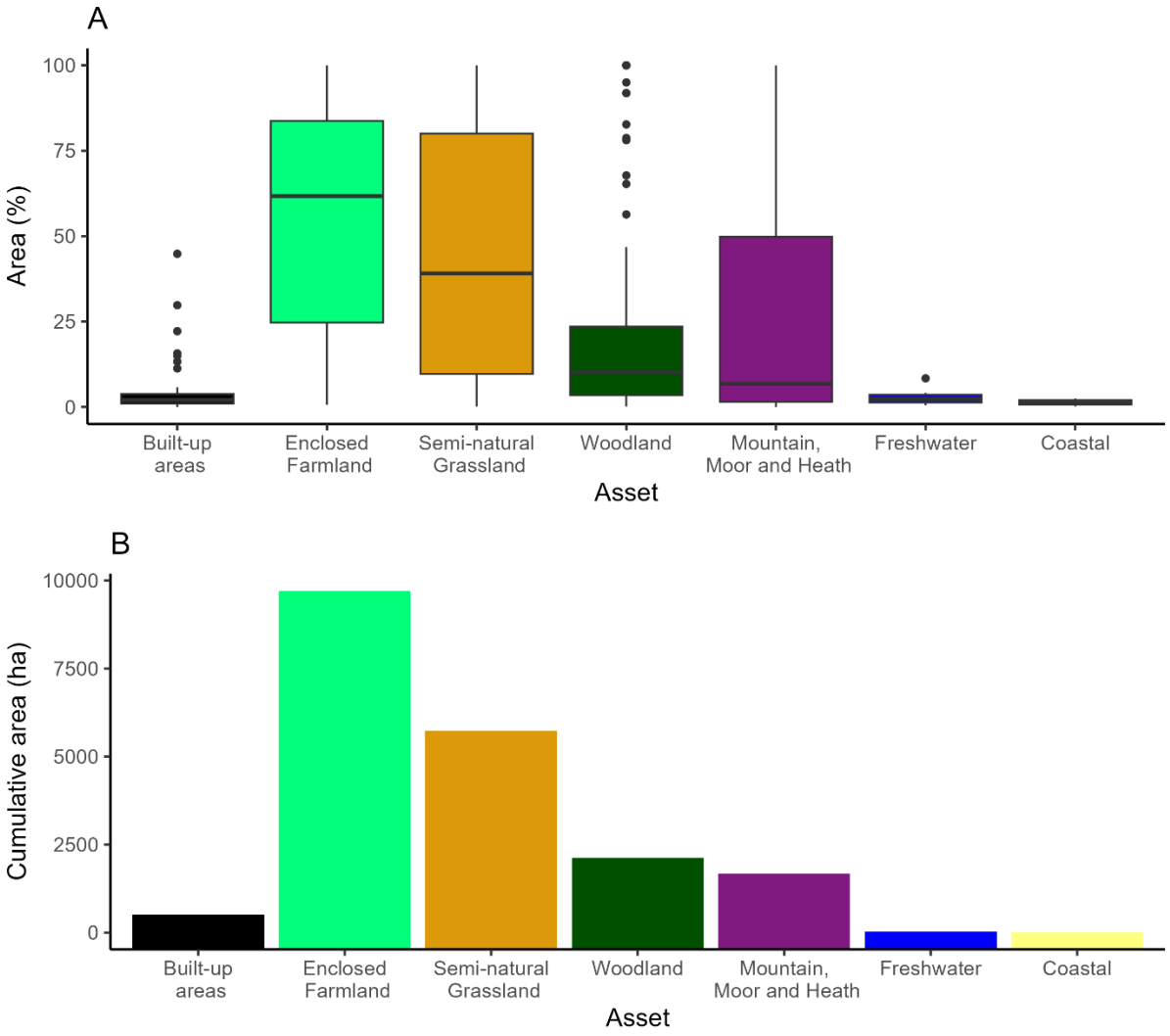

Figure 2-4 A)The distribution of detected asset class areas across Headwater monitoring sites established in 2013-16 in upstream catchments, shown as percentage of catchment area. The horizontal lines indicate the midpoint, the boxes indicate where the mid 50% of all values sit and the vertical lines represent the full range of values observed. B) The cumulative area of all upstream catchments of all Headwater monitoring sites established in 2013-16 across different habitat asset classes.

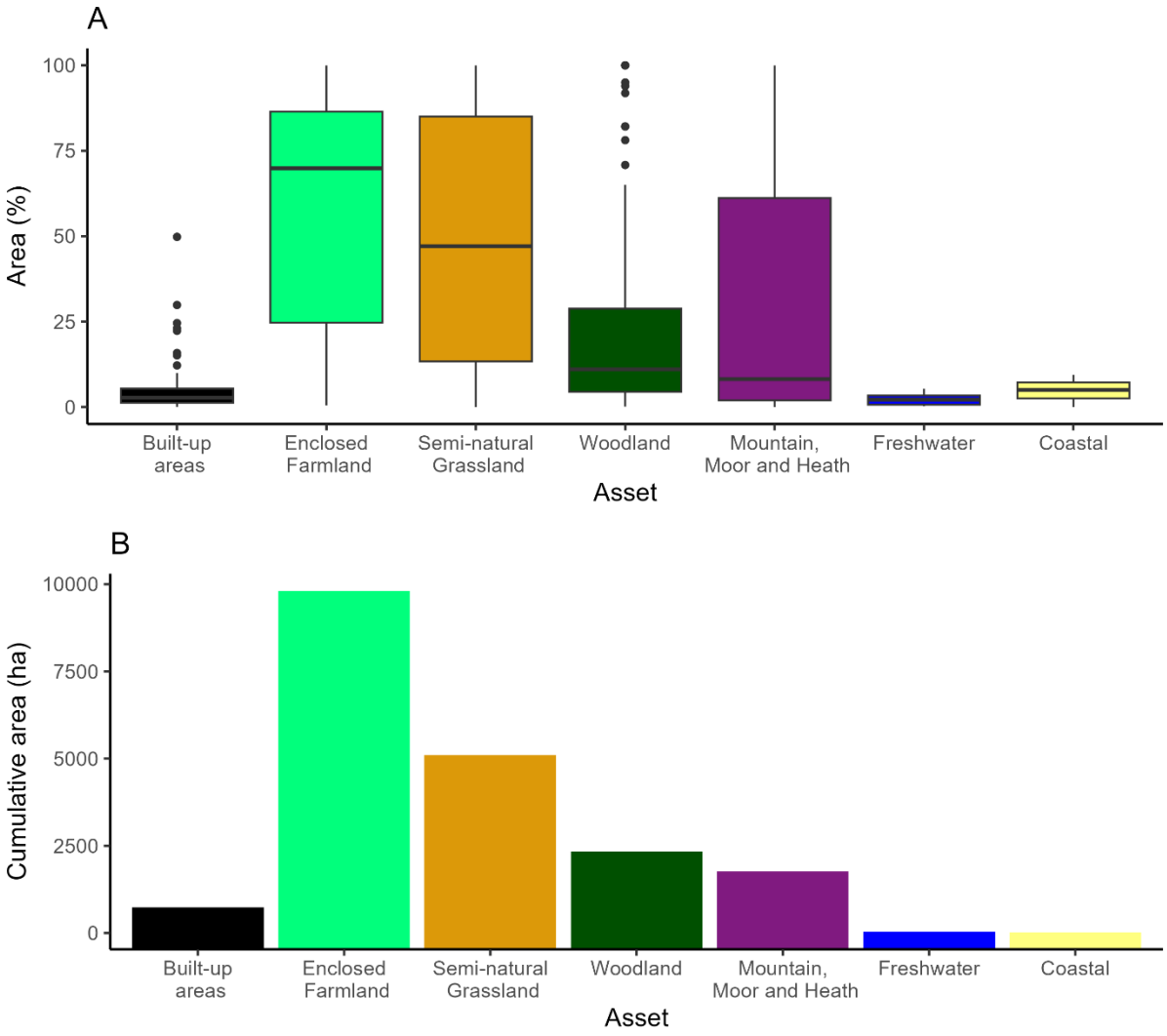

Figure 2-5 A) The distribution of detected asset class areas across Headwater monitoring sites established in 2021-23 in upstream catchments, shown as percentage of catchment area. The horizontal lines indicate the midpoint, the boxes indicate where the mid 50% of all values sit and the vertical lines represent the full range of values observed. B) The cumulative area of all upstream catchments of all Headwater monitoring sites established in 2013-16 across different habitat asset classes.

2.5 Glastir Data

Information of Glastir Option uptake within catchments was extracted to enable an analysis of the effects of Glastir Option management on our indicators over time. Glastir Options have been aggregated in to bundles of options with similar managements and intended outcomes to facilitate this analysis, and these bundles are described in more detail in ERAMMP Technical Annex-105TA1S1: Wales National Trends and Glastir Evaluation. Supplement-1: Data Analysis Methods (Jarvis et al, 2025).

Analyses of Glastir Option effect were only performed where: 1) there was an underpinning logic chain support a link between Glastir managements and the measured indicator, and 2) there was sufficient data coverage and Glastir uptake. More information on the analytical approach is given in (Jarvis et al, 2025). As a result, the effects of 1) All Glastir Options, 2) habitat management options and 3) No/Low Grazing Input options

In brief, Glastir presence is defined and quantified as the mean area in the catchment affected by any-and-all actions within a given Option bundle, over the relevant time window. For the baseline survey (2013-16) the total area in a bundle is identified for each year prior to and including the sample, since the establishment of the scheme (2012) and the mean taken across those years. For ERAMMP samples (2021-23), the same calculations are performed for all years since the previous sample up to and including the year of the current sample. If there was no previous sample taken, we took 2015 as the start point, to ensure a comparable timeframe was used, relative to other samples. The area of the catchment impacted by Glastir is then converted to a percentage of the catchment area.

Catchment coverage for historic agri-environment schemes of Tir Gofal and Tir Cynnal was also extracted using the same approach. This was incorporated in models as a control factor for historic models. Similarly, when considering the impacts of managements on catchments for all Wales and for non-enclosed farmland asset classes, we included the percentage of the catchment occupied by enclosed farmland as a control factor for overall land use intensity.

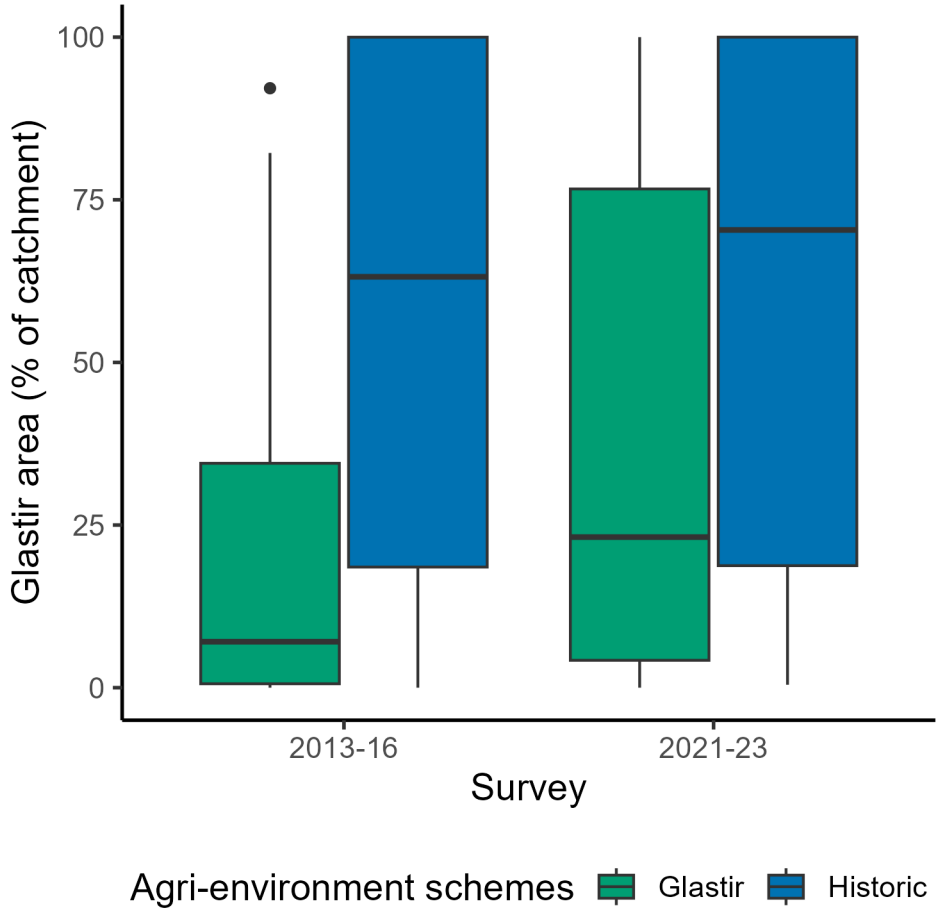

Figure 2-6 The area of Glastir options and historic AES (Tir Gofal and Tir Cynnal) across upstream catchments within the 2013-16 and 2021-23 Headwater surveys shown as a percentage of catchment area surveyed in both time periods. The horizontal lines indicates the midpoint, the boxes indicate where the mid 50% of all values sit and the vertical lines represent the full range of values observed.

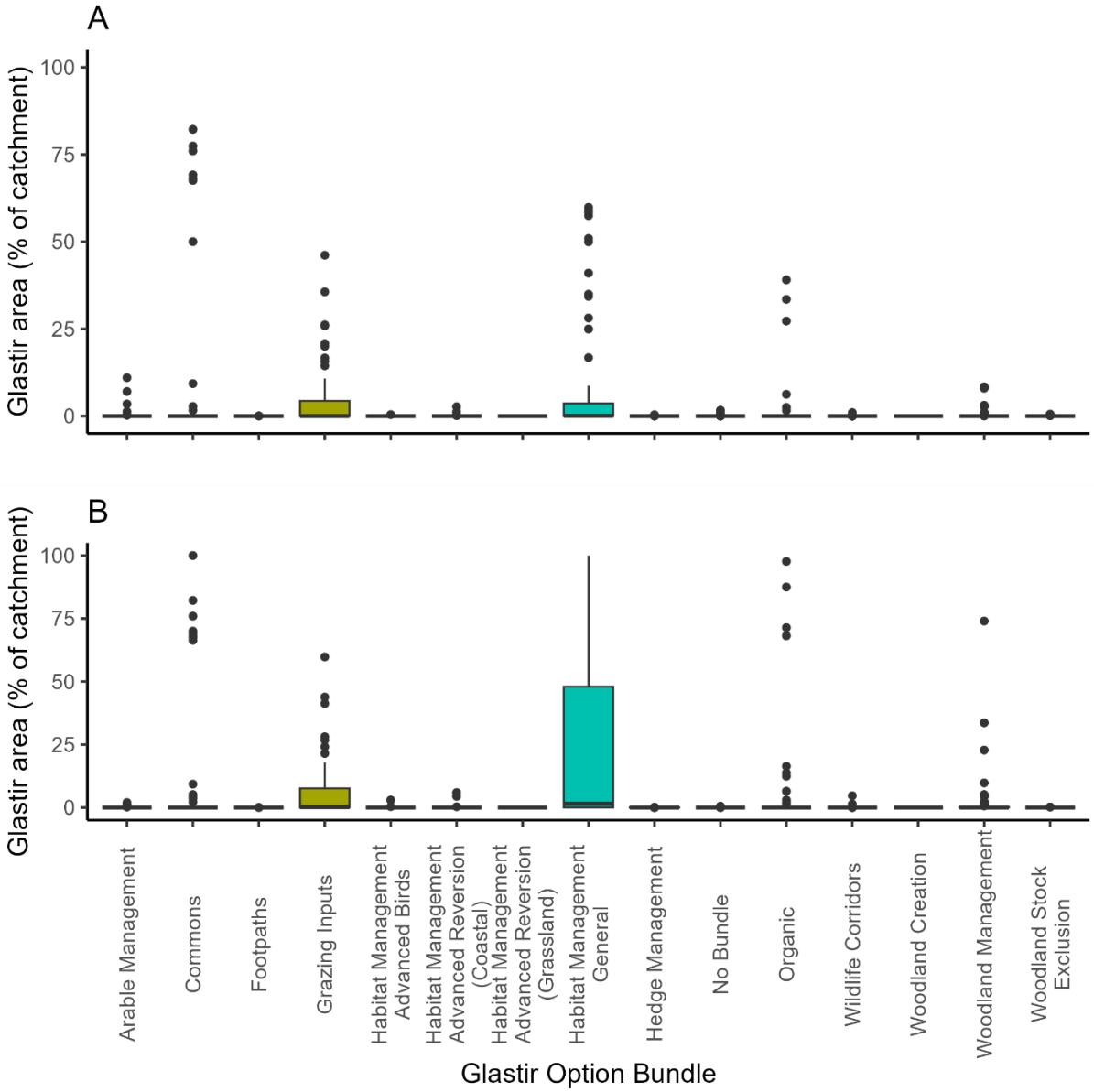

Figure 2-7 The area of Glastir options by bundle across upstream catchments within the 2013-16 and 2021-23 Headwater surveys shown as a percentage of catchment area surveyed in A) 2013-23 and B) 2021-23, for sites surveyed in both time periods. The horizontal lines indicate the midpoint, the boxes indicate where the mid 50% of all values sit and the vertical lines represent the full range of values observed.

2.6 National Trend Analysis

Here we provide the results for the National Trends in headwater indicators for All Wales and for asset classes. When considering National Trends for specific asset classes in headwaters, a weighting term was used in the model that is proportional to the percentage of each catchment in the focal asset class. Catchments for which the asset class is not present are excluded from the model. The modelling approach used here is described in greater detail in Jarvis et al, 2025.

Results tables for all analyses are provided below. For a summary of National Trend results please see Section 6.1.5 of Emmett et al, 2025.

2.6.1.1 Dry Streams

Table 2-5 Incidence of dry Headwater streams, as a percentage of Headwater streams visited, across each survey period, for all sites and for sites specifically within the Nationally Representative Sites subset of squares.

Incidence of Headwater Streams	2013-16	2021-23
Dry streams (% All sites)	2.9 (5 out of 174)	9.9 (10 out of 101)
Dry streams (% Nationally Representative Sites only)	2.6 (4 out of 150)	12.9 (8 out of 62)

2.6.1.2 Macroinvertebrate indicators of stream health

Table 2-6 Presence and relative abundance of headwaters in each category of stream condition based on the macroinvertebrate index of stream health for nationally representative sites, all where N is the number of streams. Separate counts are provided for all nationally representative sites surveyed in 2013-26 and the subset of those sites in the resurveyed population, to facilitate comparison with results form 2021-23.

Class	2013-16 (N = 82)		2013-16 Resurveyed (N = 57)		2021-23 (N = 57)	
	N	%	N	%	N	%
High	47	57.3	33	58.9	36	64.1
Good	18	22.0	11	19.6	9	16.1
Medium	17	20.7	12	21.4	9	16.1
Bad	0	0	0	0	2	3.6

Table 2-7 National Trend analysis for headwater macroinvertebrate indicators of stream health for aggregate asset classes across Wales. Mean, minimum confidence interval (CI) and maximum CI, mean change and p-values were extracted from models for periods 2013-16 and 2021-23.

Habitat	Indicator	2013-16			2021-23			Trend	
		Mean	lower CI	upper CI	Mean	lower CI	upper CI	Mean Change	P value
Wales	Macroinvertebrate Index of Stream Health (O/E WHPT – NTAXA)	1.34	1.25	1.43	1.39	1.29	1.48	0.05	0.22
	Macroinvertebrate Index of Stream Health (O/E WHPT –ASPT)	0.98	0.95	1.01	0.98	0.95	1.01	0.00	0.94
Enclosed Farmland	Macroinvertebrate Index of Stream Health (O/E WHPT – NTAXA)	1.43	1.31	1.55	1.44	1.30	1.57	0.00	0.95
	Macroinvertebrate Index of Stream Health (O/E WHPT –ASPT)	0.98	0.94	1.02	0.97	0.92	1.02	-0.01	0.77
Semi-natural grassland and Fen	Macroinvertebrate Index of Stream Health (O/E WHPT – NTAXA)	1.34	1.19	1.49	1.40	1.22	1.58	0.06	0.64
	Macroinvertebrate Index of Stream Health (O/E WHPT –ASPT)	1.00	0.96	1.04	1.00	0.95	1.05	0.00	0.88
Woodland	Macroinvertebrate Index of Stream Health (O/E WHPT – NTAXA)	1.12	0.86	1.39	1.2	0.84	1.55	0.07	0.74
	Macroinvertebrate Index of Stream Health (O/E WHPT –ASPT)	0.95	0.87	1.03	0.96	0.86	1.07	0.02	0.79
Mountain, Moor and Heath	Macroinvertebrate Index of Stream Health (O/E WHPT – NTAXA)	0.91	0.72	1.11	1.22	1.03	1.42	0.31	0.03
	Macroinvertebrate Index of Stream Health (O/E WHPT –ASPT)	0.97	0.88	1.06	1.00	0.91	1.09	0.03	0.63

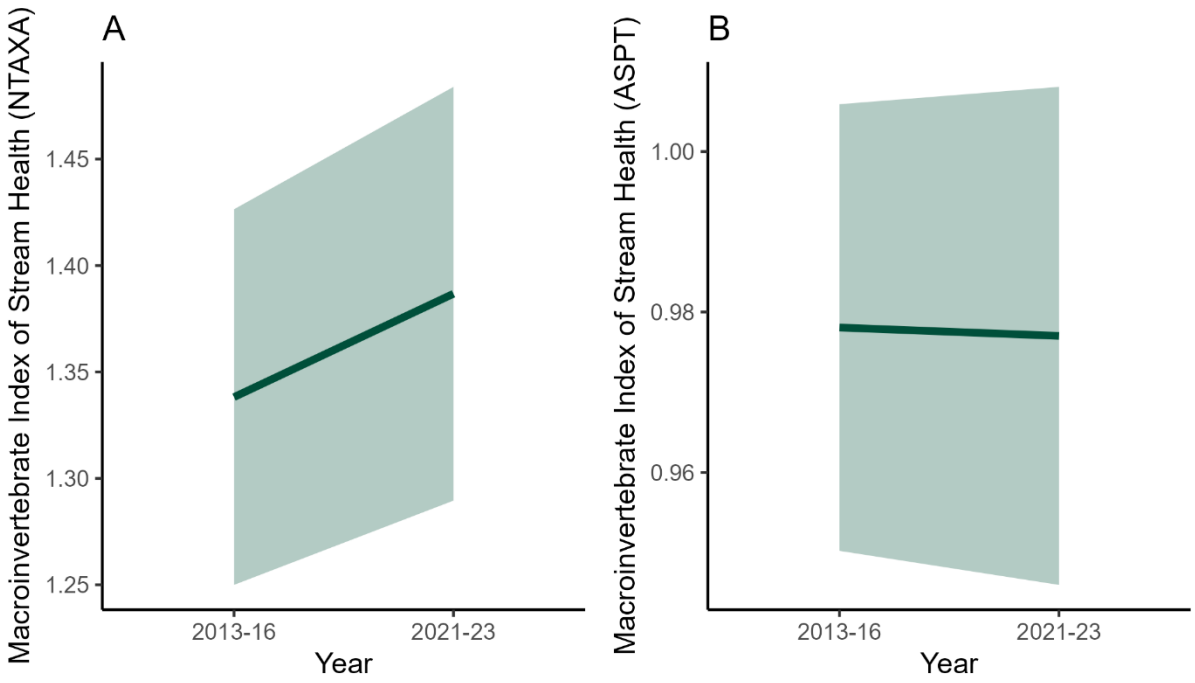

Figure 2-8 Trend in Macroinvertebrate Index of Stream Health A) NTAXA and B) ASPT metrics between 2013-16 and 2021-23 from nationally representative survey squares.

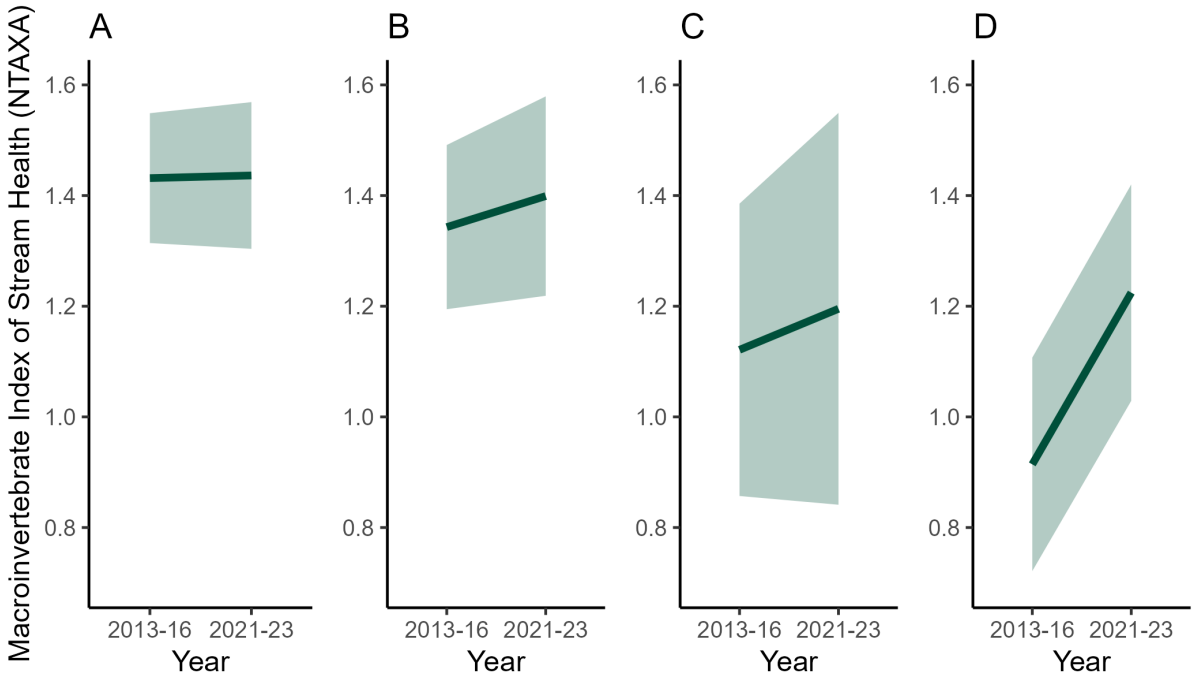

Figure 2-9 Trend in Macroinvertebrate Index of Stream Health NTAXA between 2013-16 and 2021-23 from nationally representative survey squares weighted by Asset Class area for A) Enclosed Farmland, B) Semi-Natural Grassland and Fen, C) Woodland and D) Mountain, Moor and Heath.

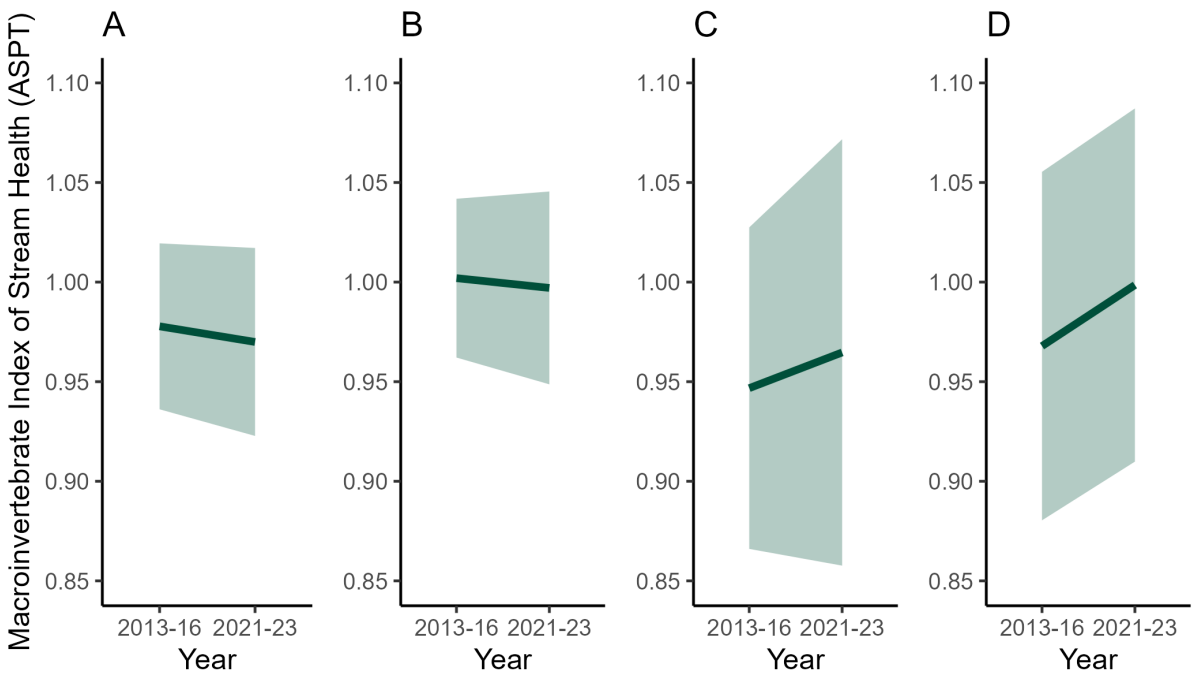

Figure 2-10 Trend in Macroinvertebrate Index of Stream Health ASPT between 2013-16 and 2021-23 from nationally representative survey squares weighted by Asset Class area for A) Enclosed Farmland, B) Semi-Natural Grassland and Fen, C) Woodland and D) Mountain, Moor and Heath.

2.6.1.3 Macroinvertebrate sediment Index

Table 2-8 Presence and relative abundance of headwaters in each category of stream condition based on the Macroinvertebrate sediment Index for nationally representative sites, all where N is the number of streams. Separate counts are provided for all nationally representative sites surveyed in 2013-26 and the subset of those sites in the resurveyed population, to facilitate comparison with results form 2021-23.

PSI Class	2013-16 (N = 81)		2013-16 Resurveyed (N = 55)		2021-23 (N = 55)	
	N	%	N	%	N	%
Minimally Sedimented / Unsedimented	22	27.2	16	29.1	12	21.4
Slightly Sedimented	29	35.8	21	38.2	20	35.7
Sedimented	11	13.6	7	12.7	7	12.5
Moderately Sedimented	15	18.5	7	12.7	11	19.6
Heavily Sedimented	4	4.9	4	7.3	6	10.7

Table 2-9 National Trend analysis for Macroinvertebrate sediment Index for aggregate asset classes across Wales. Mean, minimum confidence interval (CI) and maximum CI, mean change and p-values were extracted from models for periods 2013-16 and 2021-23.

Habitat	Indicator	2013-16			2021-23			Trend	
		Mean	lower CI	upper CI	Mean	lower CI	upper CI	Mean Change	P value
Wales	Macroinvertebrate sediment Index (O/E PSI) [1]	0.81	0.75	0.87	0.77	0.70	0.83	-0.04	0.04
Enclosed Farmland	Macroinvertebrate sediment Index (O/E PSI) [1]	0.82	0.73	0.91	0.74	0.64	0.84	-0.07	0.13
Semi-natural grassland and fen	Macroinvertebrate sediment Index (O/E PSI) [1]	0.84	0.75	0.93	0.82	0.71	0.93	-0.02	0.73
Woodland	Macroinvertebrate sediment Index (O/E PSI) [1]	0.76	0.58	0.93	0.76	0.53	0.99	0.00	0.99
Mountain, moor and Heath	Macroinvertebrate sediment Index (O/E PSI) [1]	1.01	0.88	1.15	0.91	0.77	1.04	-0.11	0.27

[1] A ±0.2 deviation from 1 indicates a decline in condition.

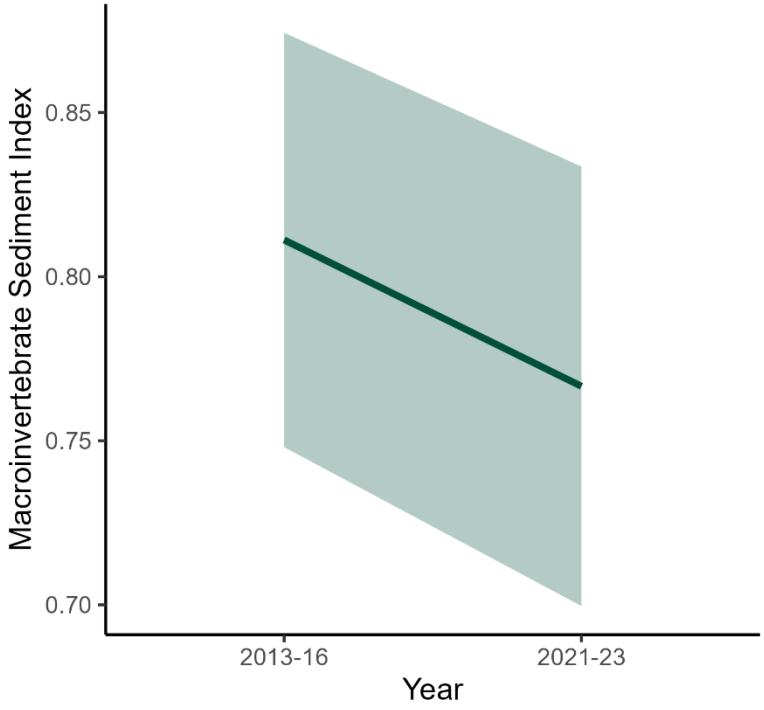

Figure 2-11 Trend in Macroinvertebrate Sediment Index between 2013-16 and 2021-23 from nationally representative survey squares.

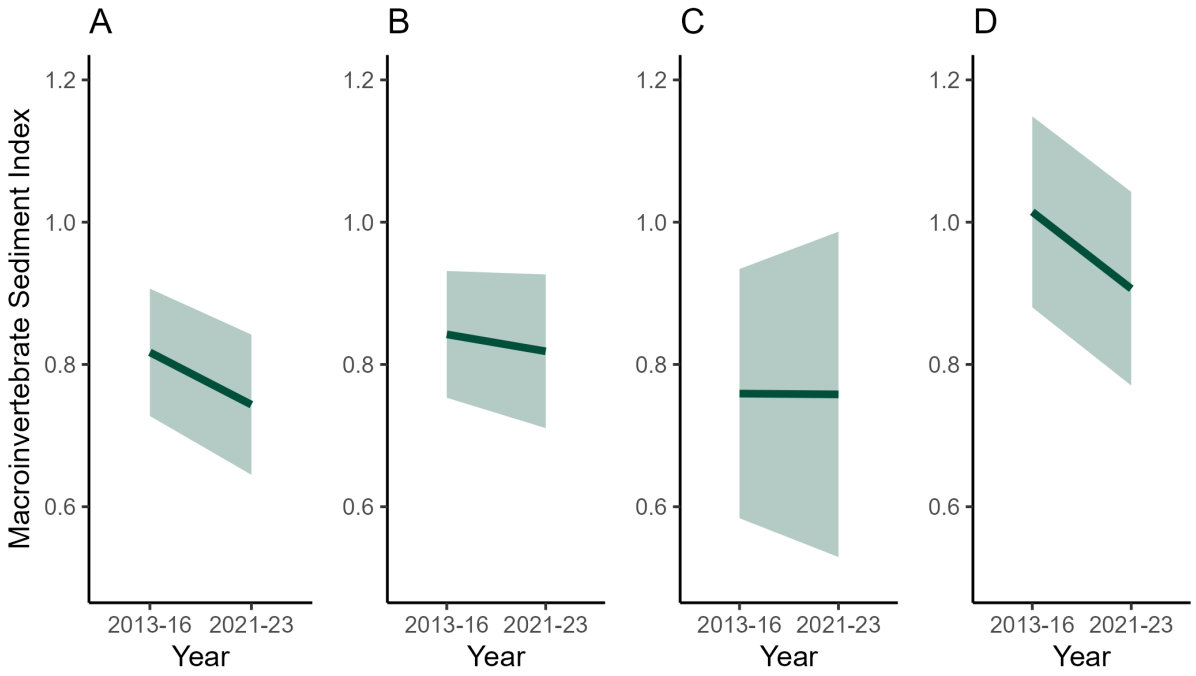

Figure 2-12 Trend in Macroinvertebrate Sediment Index between 2013-16 and 2021-23 from nationally representative survey squares weighted by Asset Class area for A) Enclosed Farmland, B) Semi-Natural Grassland and Fen, C) Woodland and D) Mountain, Moor and Heath.

2.6.1.4 Invasive Species

Table 2-10 Relative abundance and presence of invasive macroinvertebrate species in headwater streams across all surveyed headwaters and nationally representative sample sites visited in both 2013-16 and 2021-23.

	2013-16		2021-23	
	All sites (N=89)	Nationally Representative Sites (N= 56)	All sites (N=89)	Nationally Representative Sites (N=56)
Invasive species richness (Mean % of taxa)	1.4	1.5	1.4	1.9
Invaded streams (%)	53.9	58.9	49.4	66.1
Invasive abundance (Mean % of individuals)	5.2	7.6	5.7	7.1

Table 2-11 Number of nationally representative sites at which invasive taxa were present within headwater streams and total abundance of those invasives across nationally representative sites. Separate counts are provided for all nationally representative sites surveyed in 2013-16 and the subset of those sites in the resurveyed population, to facilitate comparison with results form 2021-23. N is the number of streams surveyed in the nationally representative population.

Invasive taxa	Streams with invasive invertebrate species					
	2013 -2016 (N =82)		2013-2016 resurveyed (N = 56)		2021-2023 (N = 56)	
	Sites	Abundance	Sites	Abundance	Sites	Abundance
Crangonyx pseudogracilis	5	226	4	168	8	1055
Physella acuta group	3	418	3	418	1	23
Planaria torva	5	13	3	10	2	3
Potamopyrgus antipodarum	39	35107	29	23841	31	13347
Girardia tigrina	0	0	0	0	1	1

2.7 Glastir Analysis

Here we provide the results for the Glastir analysis in headwater indicators for All Wales and for asset classes, where possible. In addition to the effects of Glastir, Glastir bundles and survey (2013-16 or 2021-23) used in the models, additional terms were included to control for the different landscape and historical contexts across sites. These are:

- Presence of historic agri-environment scheme management in the past (see Section 2.5 Glastir data)
- Land use intensity in the surrounding area. In this context, this was captured through the percentage of a catchment within the Enclosed Farmland asset class.

Due to the distributions of the different Glastir bundles across asset classes, it was decided that there was insufficient data coverage across the different catchments and asset classes to support reporting on Glastir options for the separate catchment asset classes. The modelling approach used here is described in greater detail in Jarvis et al, 2025, including a description of model structures. Results tables for all analyses are provided below. For a summary of Glastir analysis results please see Section 6.1.6 of Emmett et al, 2025.

2.7.1.1 Macroinvertebrate Index of Stream Health

Table 2-12 Glastir analysis for Macroinvertebrate Index of Stream Health for All Wales. Glastir management bundles assessed for effects on indictors are shown, but greyed out where data did not allow for analysis. Reported Glastir effect is a difference in the rate of change in the indicator over time between sites within the relevant bundle and those out of it, where a positive number shows a more positive change where Glastir was present (a larger increase of smaller decrease).Context effect was tested using information related to participation in historic agri-environment schemes and enclosed farmland cover to control for any background effects on the observed rate of change over time.

Asset Class	Indicator	Glastir Option Bundle	Glastir Effect	P value	Context effect on change
All Wales	Macroinvertebrate Index of Stream Health (O/E WHPT – NTAXA)	All Glastir	-0.02	0.86	No
		Habitat Management	0.00	0.99	No
		Grazing inputs	-0.12	0.46	No
	Macroinvertebrate Index of Stream Health (O/E WHPT –ASPT)	All Glastir	-0.02	0.57	No
		Habitat Management	0.02	0.49	No
		Grazing inputs	-0.03	0.82	No

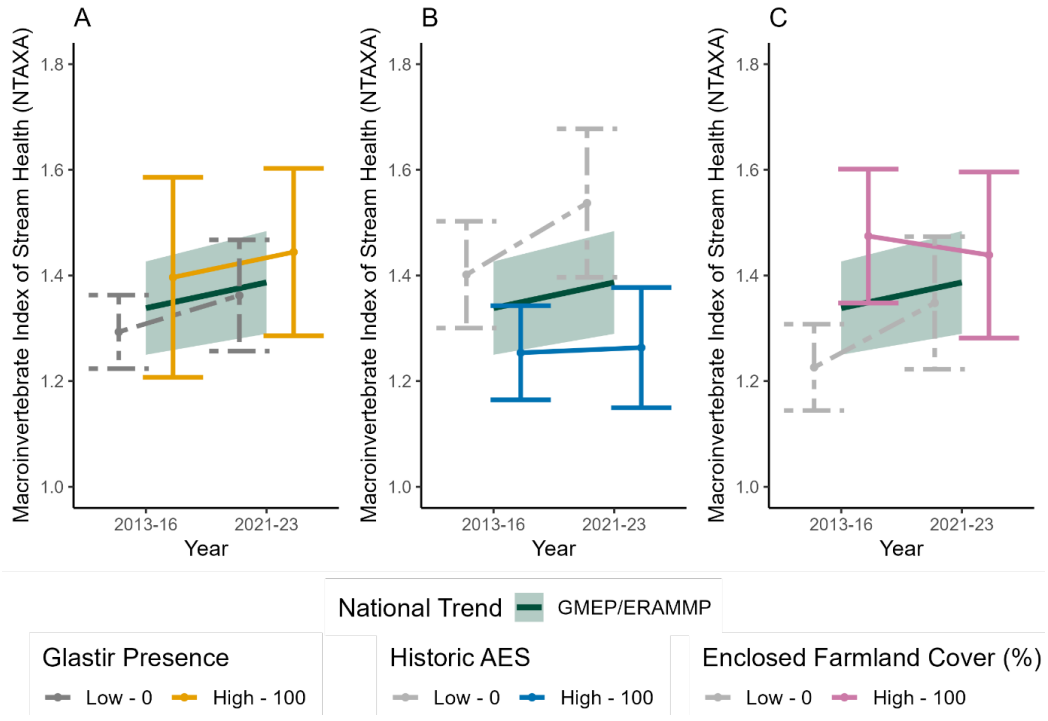

Figure 2-13 Trend in Macroinvertebrate Index of Stream Health NTAXA between 2013-16 and 2021-23 for All Wales showing both National Trends and effect of uptake of A) Glastir Option uptake when low (0%) or high (100%), B) Historic Agri-Environment Scheme Option uptake when low (0%) or high (100%), C) Enclosed Farmland Cover within the Catchment when low (0%) or high (100%).

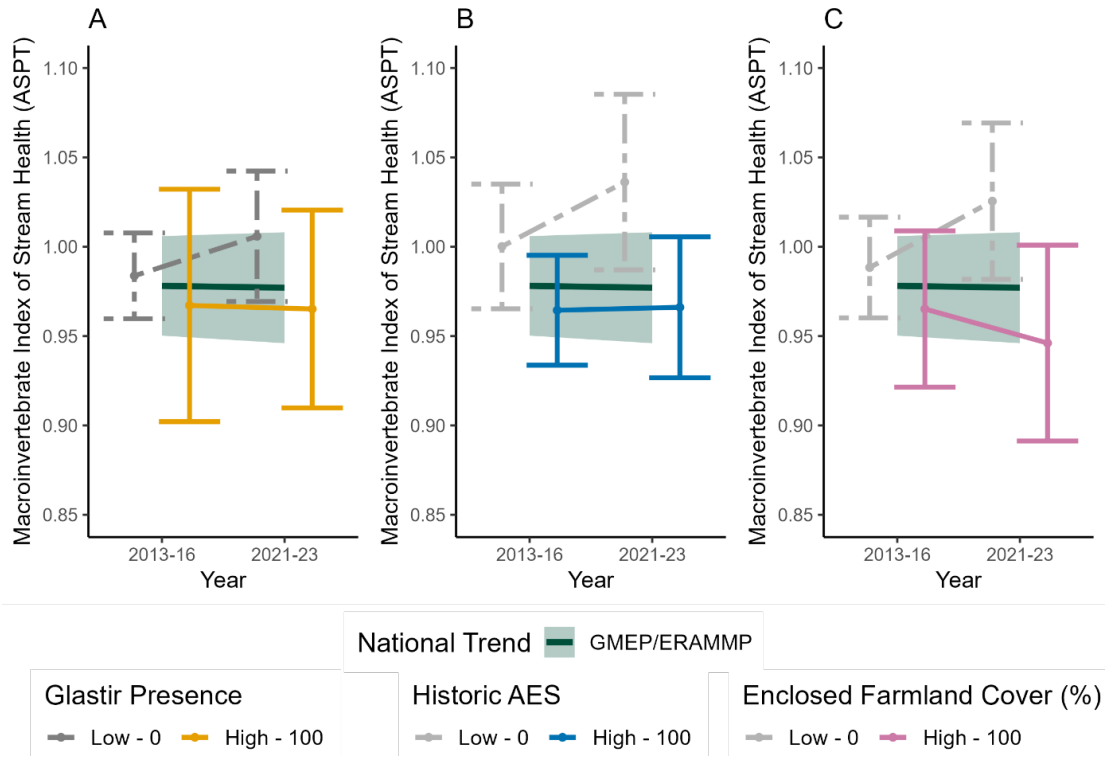

Figure 2-14 Trend in Macroinvertebrate Index of Stream Health ASPT between 2013-16 and 2021-23 for All Wales showing both National Trends and effect of uptake of A) Glastir Option uptake when low (0%) or high (100%), B) Historic Agri-Environment Scheme Option uptake when low (0%) or high (100%), C) Enclosed Farmland Cover within the Catchment when low (0%) or high (100%).

2.7.1.2 Macroinvertebrate sediment Index (O/E PSI)

Table 2-13 Glastir analysis for Macroinvertebrate sediment Index for All Wales. Glastir management bundles assessed for effects on indictors are shown, but greyed out where data did not allow for analysis. Context effect was tested using information related to participation in historic agri-environment schemes and enclosed farmland cover.

Asset Class	Indicator	Glastir Option Bundle	Glastir Effect	P value	Context effect on change
All Wales	Macroinvertebrate Sediment Index (O/E PSI)	All Glastir	-0.03	0.69	No
		Habitat Management	-0.02	0.64	Yes
		Grazing inputs	-0.07	0.43	Yes

[1] This differs to the context effect reported in the main text. In the main text we included effects of context variables on mean scores across both time periods (not included here) as well as effects of context variables on the rate of change.

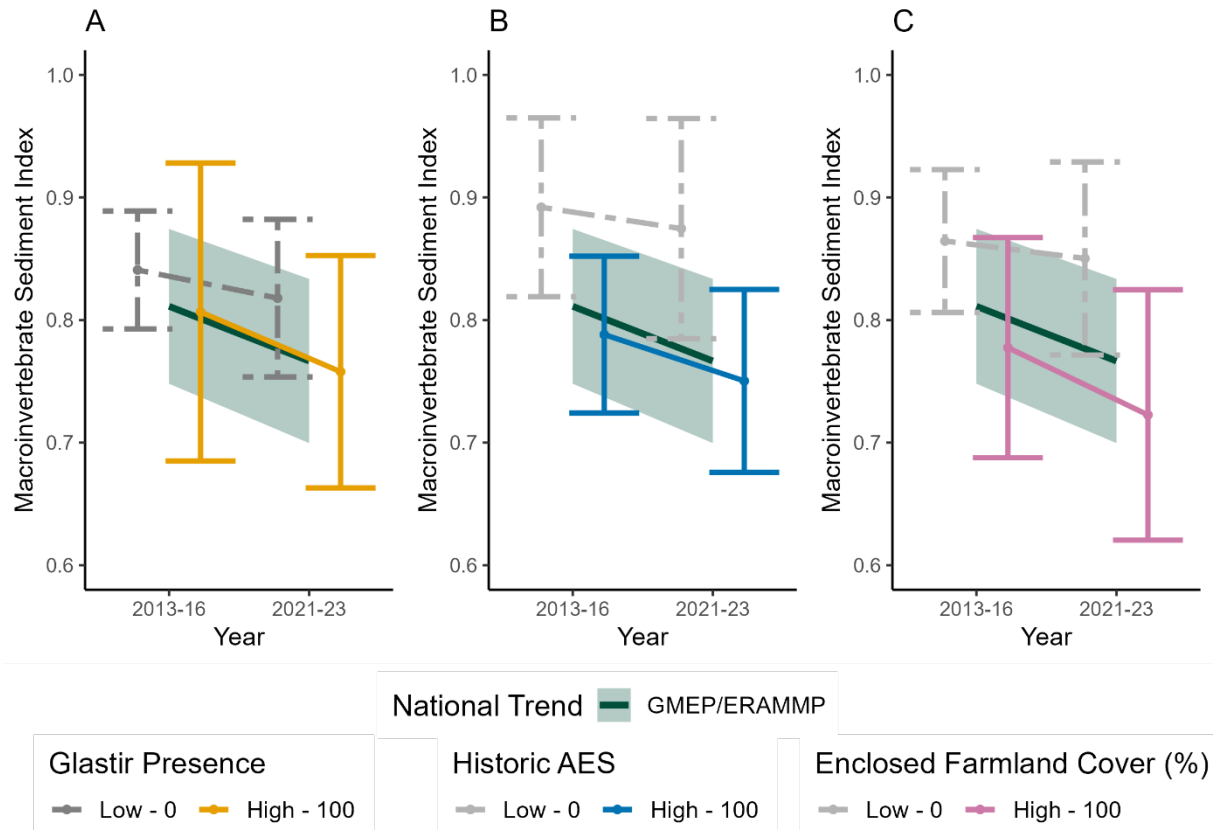

Figure 2-15 Trend in Macroinvertebrate Sediment Index between 2013-16 and 2021-23 for All Wales showing both National Trends and effect of uptake of A) Glastir Option uptake when low (0%) or high (100%), B) Historic Agri-Environment Scheme Option uptake when low (0%) or high (100%), C) Enclosed Farmland Cover within the Catchment when low (0%) or high (100%).

3 HEADWATERS - STREAMSIDES

The survey of headwaters is based on first or second order streams that fall within the 300 1km squares surveyed in GMEP, and the subset of 224 squares resurveyed in the ERAMMP. The selection of sites for resurvey is described in Alison et al, 2021 and summarised in Jarvis et al, 2025. In all survey years, streamsides were surveyed in each square that contained a suitable stream. In the original survey (2013-16) where squares contained multiple suitable streams, one was chosen at random and that stream was subsequently revisited.

The field survey of streamsides contains three separate workflows (Figure 3-1):

- River habitat survey conducted over a 500m section of stream bank
- Streamside erosion feature survey
- Streamside vegetation plot survey

The streamside vegetation plot survey is conducted as part of the ERAMMP vegetation survey and is not discussed in further detail here.

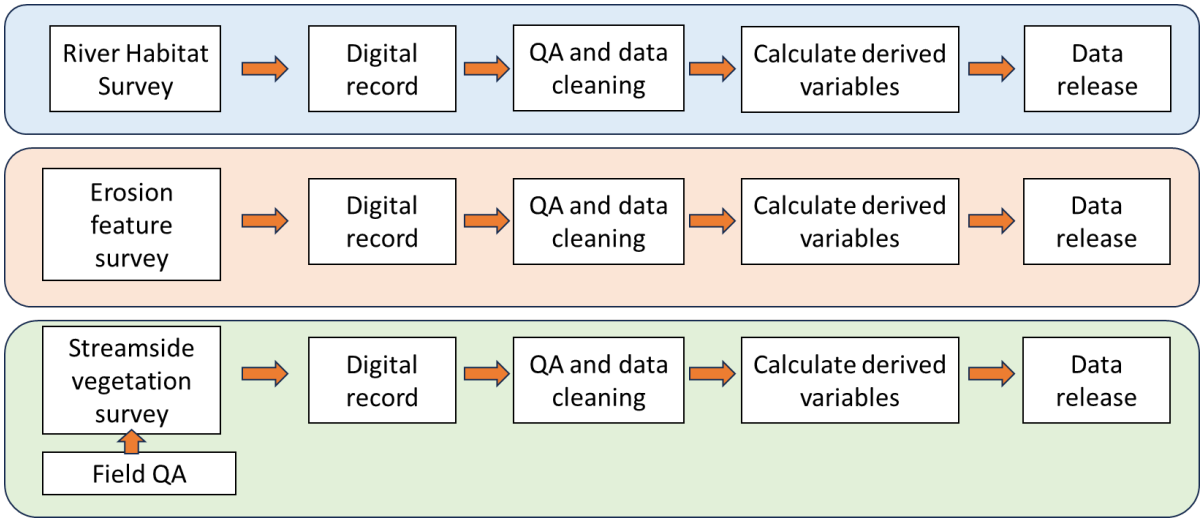

Figure 3-1 Data collection and processing pathways for data collected within the streamsides monitoring in the ERAMMP and GMEP monitoring programs.

|A full description of the field survey methods used is provided in Scarlett, et al. (2021) and Scarlett & Wood (2023). Data cleaning and integrity checks are performed by UKCEH. In all cases, variables were calculated using consistent methods for all surveyed time periods. The stream erosion feature survey is a new addition to the monitoring scheme and is reported for the first time in 2021-23. It should be noted that the frequencies of poaching reported through the river habitat survey and erosion feature survey differ for 2021-23. This is because the erosion feature survey is a more targeted and thorough record of erosion presence, where small amounts of poaching not detectable through standard RHS survey practices should be captured. In the limited cases (3) where poaching was reported for streams during the erosion survey but not during the RHS survey, the total length of bank with poaching was less than 10m in over both backs across the 500m survey.

3.1 Dataset Overview

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 (cite). 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 (Nationally representative sites) were revisited but only 78 of the Targeted squares (which targeted areas with high Glastir Option uptake), due to cost limitations. However, not all squares contain relevant features for streamsides. Additional information can be found in Jarvis et al. (2025).

Raw data coverage across all years of the first survey (GMEP, 2013-16) and recent resurvey (ERAMMP, 2021-23) is provided in Table 3-1. Each site is surveyed once per survey cycle. Data coverage can differ across aspects of the headwater survey due to:

- Incomplete landowner permissions for the River Habitat Survey
- Inaccessible areas or changes in accessibility in the field

Table 3-1 Squares surveyed during GMEP and ERAMMP National Field Survey of streamsides

Data	GMEP (2013-16)				ERAMMP (2021-23)		
	2013	2014	2015	2016	2021	2022	2023
River habitat survey	35	51	36	32	59	3	37
Erosion feature Survey	-	-	-	-	59	2	38

For all freshwater survey sites, the area of influence around the streamside is defined by a 100m buffer around the survey length. As with all survey locations in ERAMMP, exact survey locations are not disclosed. However, the coverage of survey sites within WFD river catchments for both surveys (2013-16 and 2021-23) is provided in Figure 2-3.

3.2 Data Quality Assurance

All data used in these analyses have been subject to quality assurance. This includes:

- Manual inspection and verification of reported survey locations and erosion feature types against historic reports and photographs.
- Inspection of all raw data and derived variables against known ecological limits and historic reporting
- Confirmation of data continuity and integrity across survey strands

In addition, surveyor training and procedures are reviewed on an annual basis. Reporting methods and methods used in the derivation of all reporting variables are reviewed for each reporting cycle.

Due to changes in land access permissions over time, it was not always possible to survey a completely identical section of river bank for the River Habitat Survey. In all cases the area of interest around the surveyed stream bank overlapped by a minimum of 47.6% and a median of 90.4%. We hypothesised that any differences in the exact location of the transect would add noise to the analysis but not bias and confirmed this in a preliminary analysis of change in habitat modification score (trend = -0.24, p value = 0.98) and the poaching sub-score (trend = -0.13, p value = 0.65), as functions of the overlap in resurveyed area (Figure 3-1).

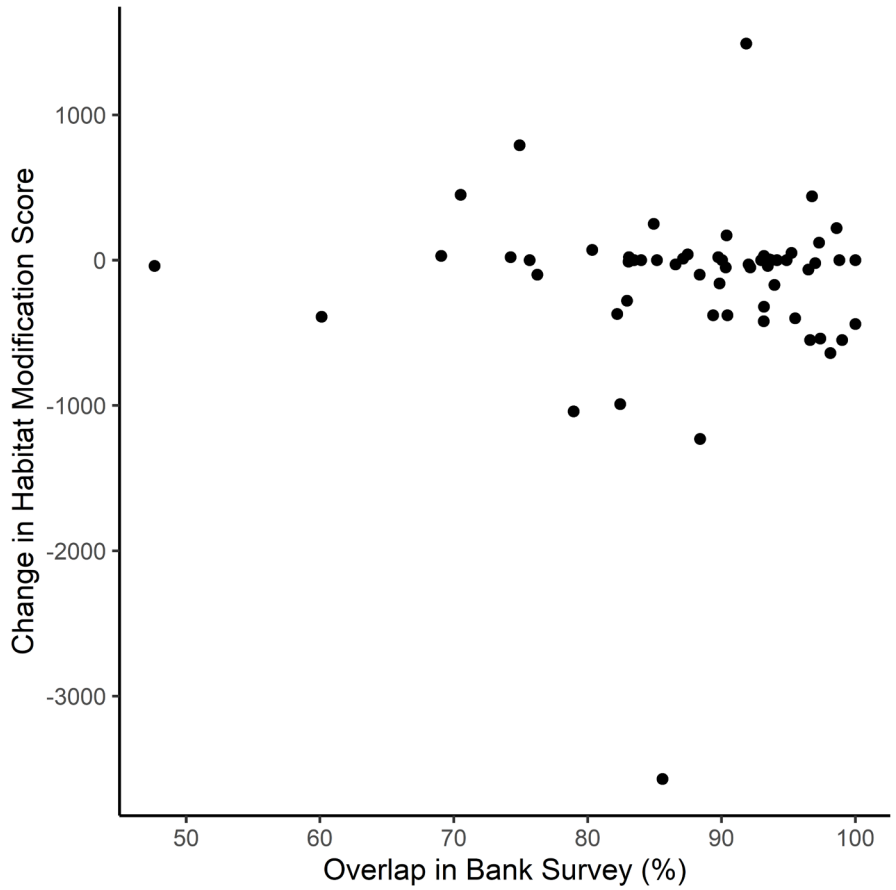

Figure 3-2 Change in habitat modification score from 2013-16 to 2021-23 with variable overlaps between survey transects due to shifting land access permissions over time.

3.3 Derived Indicators

The following indicators and metrics are reported on in ERAMMP Report-105TA1: Wales National Trends and Glastir Evaluation Section 6.2.2 using the streamside dataset for status and change in condition over both survey periods:

- Habitat modification score
- Poaching habitat modification sub-score
- Indices derived from the vegetation streamside plot which are not discussed further in this annex

In addition, metrics of erosion feature presence and extent were derived for the first time in 2021-23 from the new streamside erosion feature survey.

A description of the meaning of these indicators in a stream health context is provided in Section 6.2.2 of Emmett et al. (2025).

The Habitat Modification Score and it's sub scores are calculated following published procedures (Environment Agency, 2003) from the River Habitat Survey. Each bank of the 500m transect is scored for the presence and extent of various streamside modifications, where features are either not present (score of 0), present or extensive (a higher score). The magnitude of the score for presence of extensive modification varies with the type of modification in question.

Scores are then aggregated across stream banks and types of modification to form the sub-scores and total score reported in Emmett et al. (2025).

3.4 Habitat Classification

Habitat coverage across streamsides was assessed using the UKCEH Land Cover Map. Habitat cover was assessed for 2013-16 using a 2010 product and for 2021-23 using a 2021 product, derived using identical methods to the 2021 products published for the UK (Marston, et al., 2022). Habitat cover was assessed for a 100m radius around the 500m survey transect for streamsides, which is used for both the River Habitat Survey and the erosion feature survey. The classifications provided by Land Cover Map were aggregated to provide greater compatibility with the broad habitat classification and asset classes used elsewhere within ERAMMP reporting, as described in Table 2-3. Aggregated broad habitats were subsequently used in all assessments of catchment habitat cover.

For all subsequent analysis where habitat cover was considered, we used the habitat cover at the beginning of the survey period corresponding to the 2010 Land Cover Map. Analyses were performed for 1) All Wales, 2) Enclosed Farmland, 3) Semi-natural Grassland and fen, 4) Woodland.

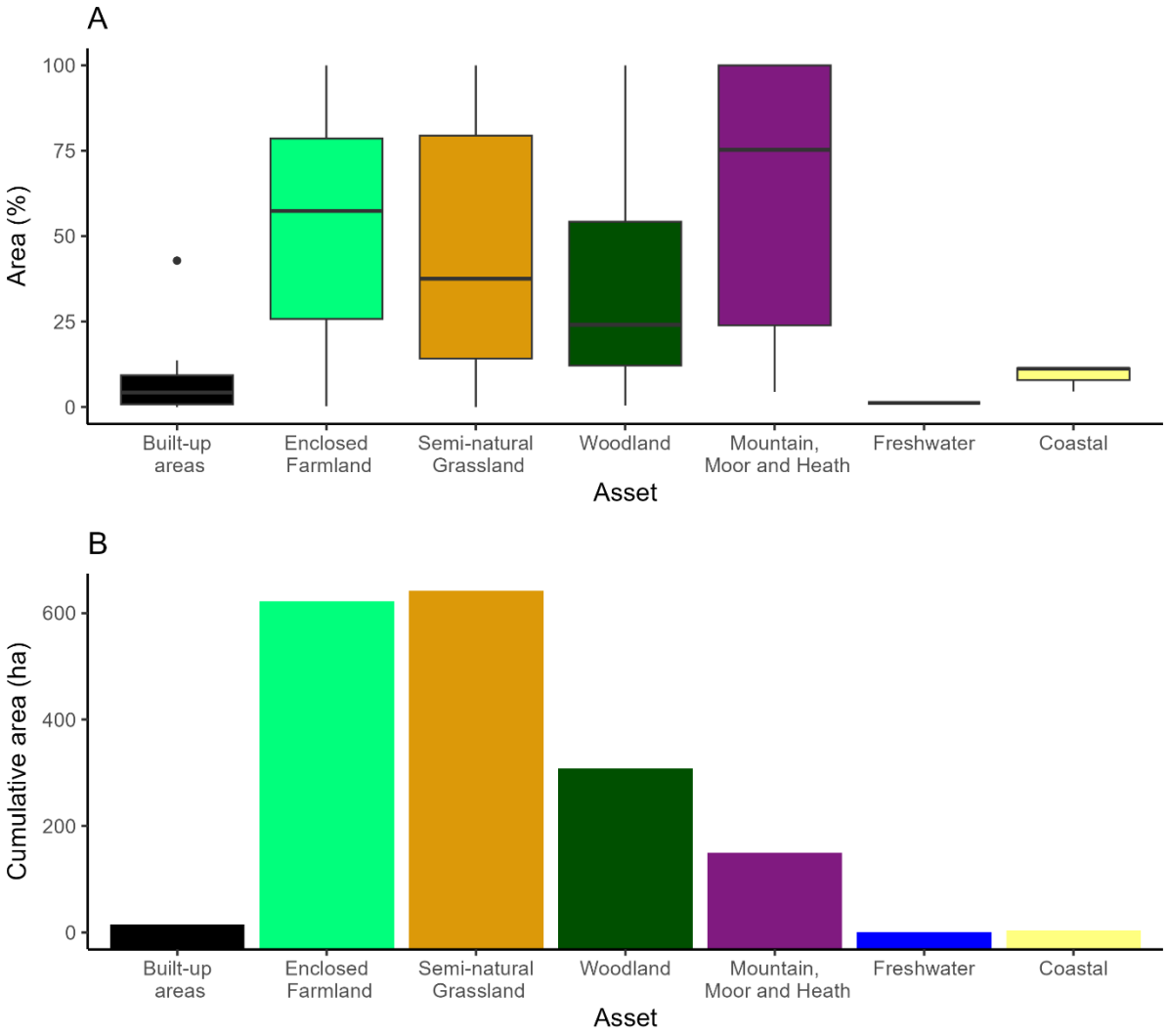

Figure 3-3 A) The distribution of detected asset class within a 100m radius of all Streamside monitoring transects established in 2013-16, as a percentage of total across different habitat asset classes. The horizontal lines indicates the midpoint, the boxes indicate where the mid 50% of all values sit and the vertical lines represent the full range of values observed. B) Cumulative area of asset classes represented within a 100m radius of all stream bank monitoring transects established in 2013-16.

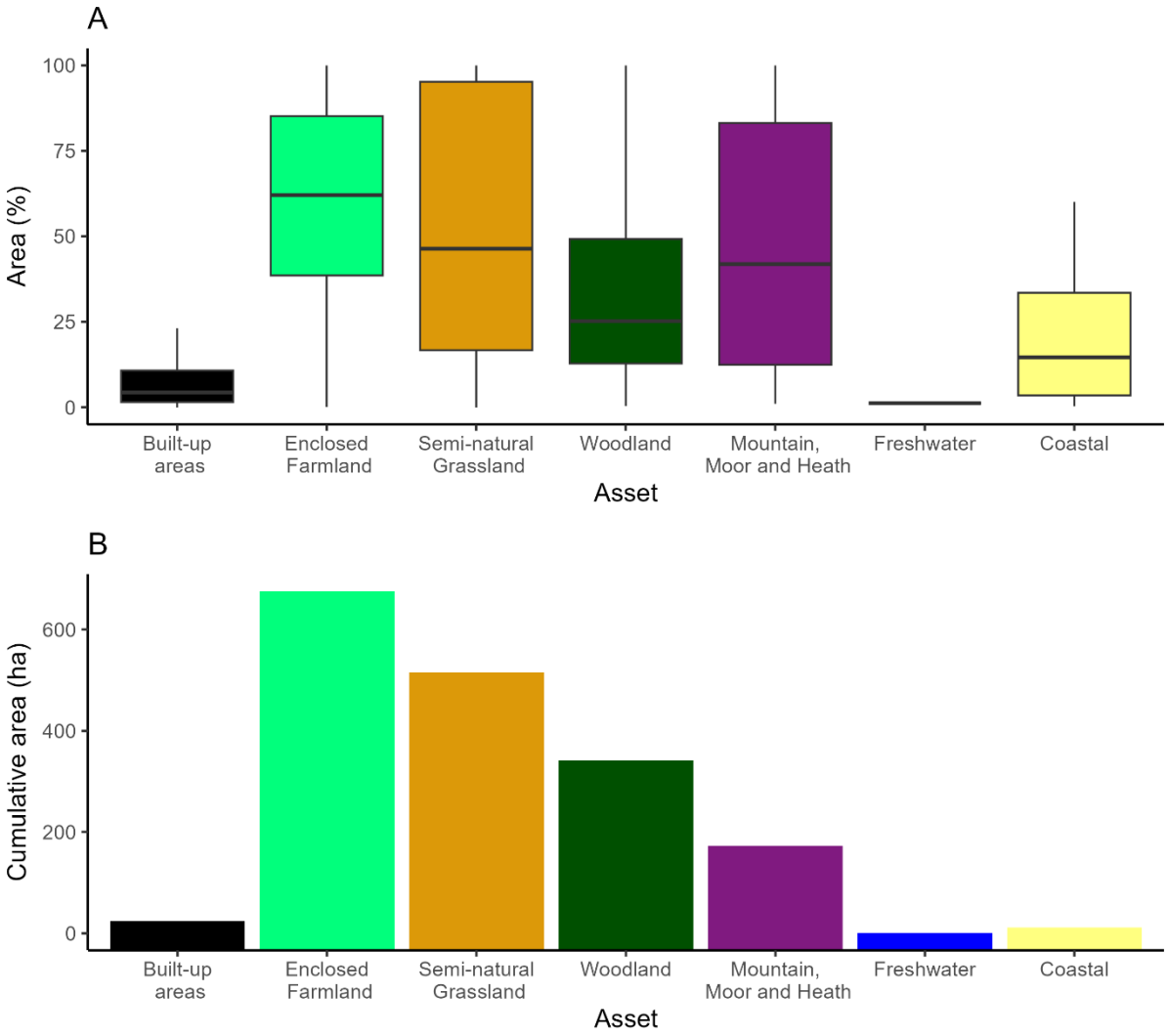

Figure 3-4 A) The distribution of detected asset class within a 100m radius of all Streamside monitoring transects established in 2021-23, as a percentage of total across different habitat asset classes. The horizontal lines indicates the midpoint, the boxes indicate where the mid 50% of all values sit and the vertical lines represent the full range of values observed. B) Cumulative area of asset classes represented within a 100m radius of all streamsides monitoring transects established in 2021-23.

3.5 Glastir Data

Information of Glastir option uptake within 100m of streamside survey transects was extracted to enable an analysis of the effects of Glastir management on our indicators over time. Glastir option have been aggregated in to bundles of options with similar managements and intended outcomes to facilitate this analysis, and these bundles are described in more detail in Jarvis et el. (2025). Analyses of Glastir Option effects were only performed where 1) there was an underpinning logic chain support a link between Glastir managements and the measured indicator, and 2) there was sufficient data coverage and Glastir uptake. As a result, we considered the effects of 1) All Glastir, 2) Habitat management, 3) Low/No Grazing inputs, 4) Wildlife corridors (which consisted of primarily streamside actions for these sites) and 5) Woodland management.

Glastir coverage for streamsides was defined for each Glastir Option bundle and for Glastir as a whole. In each case, we extracted all contributing actions that occurred within a 100m buffer of the transect for each year. Glastir was defined as present if any action within the

relevant bundle was applied in the relevant period. For data collected in 2013-16 we considered years from the start of Glastir (2012) up to and including the sampling year. For data collected in 2021-23 we considered years after the previous sample was collected, up to and including the current year of sample collection. If no previous sample was collected, we assumed a baseline of 2015 (the mean sampling date from 2013-16).

Coverage for historic agri-environment schemes of Tir Gofal and Tir Cynnal was also extracted using the same approach, where historic management was present if either Tir Gofal and Tir Cynnal occurred in any prior year.

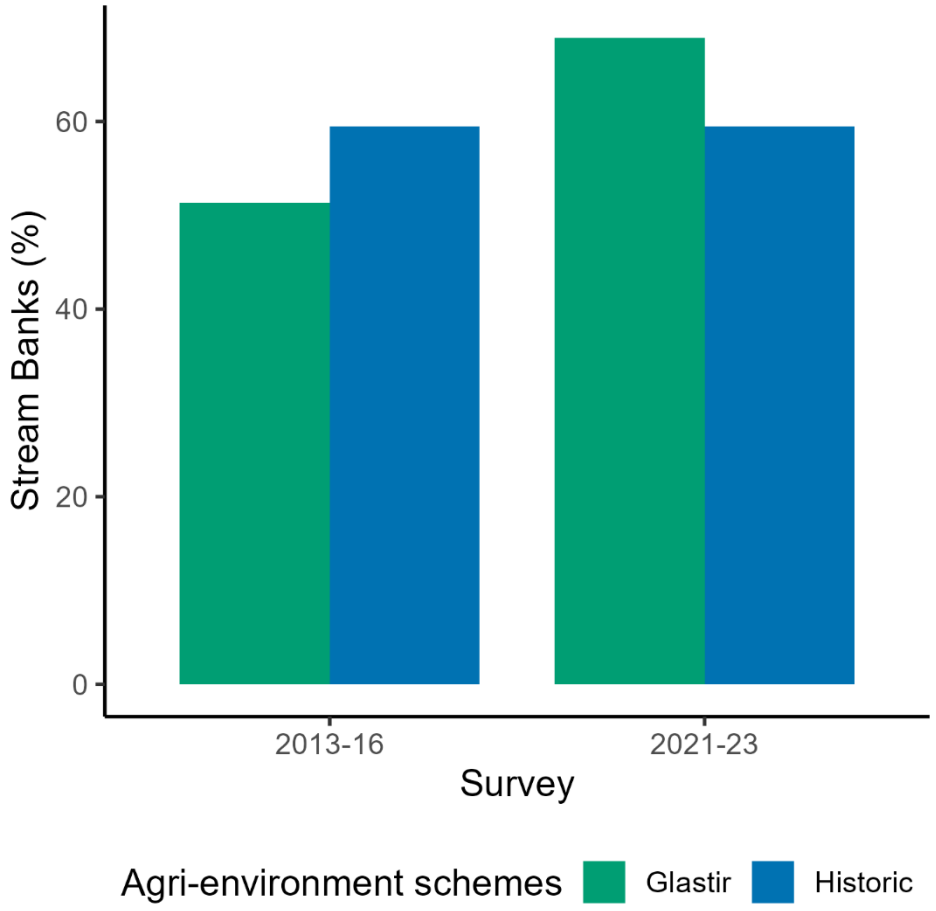

Figure 3-5 The presence of Glastir options and historic AES (Tir Gofal and Tir Cynnal) within 100m of Streamsides during the 2013-16 and 2021-23 surveys,

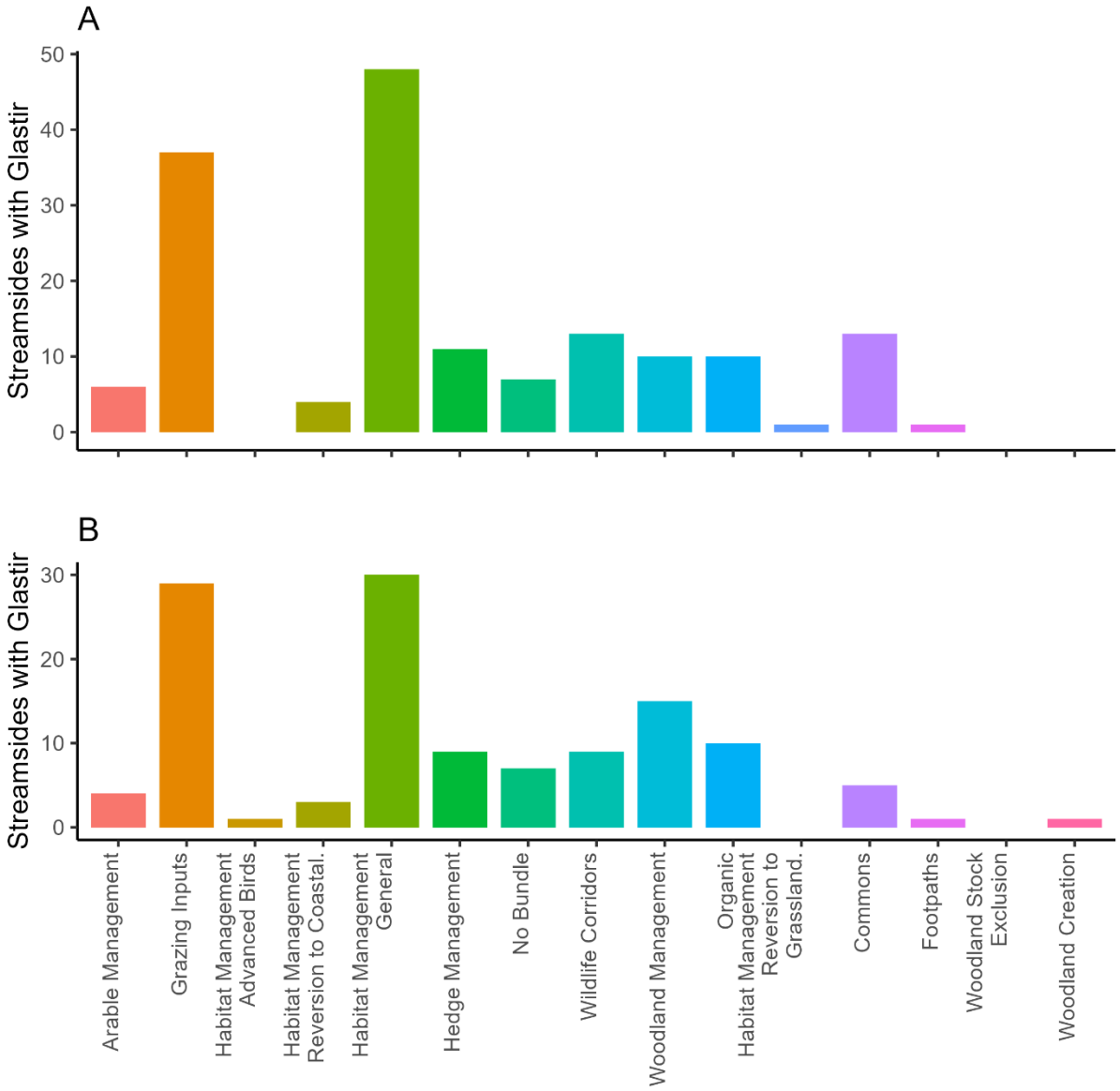

Figure 3-6 The number of surveyed streamsides with Glastir options present, by bundle within the A)2013-16 and B)2021-23. Headwater surveys shown as a percentage of catchment area surveyed in A) 2013-23 and B) 2021-23, for streams that were resurveyed.

3.6 National Trend Analysis

Here we provide the results for the National trends in streamside indicators for All Wales and for asset classes, where possible. When considering National Trends for specific asset classes a weighting term was used in the model that is proportional to the percentage of the surrounding area (100m radius) in the focal asset class. Streamsides for which the asset class is not present are excluded from the model. The modelling approach used here is described in greater detail in Jarvis et al. (2025).

Results tables for all analyses are provided below. For a summary of National Trend results please see Section 6.2.5 of Emmett et al. (2025).

3.6.1.1 Habitat Modification Score

Table 3-2 Presence and relative abundance of headwaters in each category of stream condition based on the habitat modification score for nationally representative sites, all where N is the number of streamsides. Separate counts are provided for all nationally representative sites surveyed in 2013-26 and the subset of those sites in the resurveyed population, to facilitate comparison with results form 2021-23.

Class	2013-16 (N = 80)		2013-16 Resurveyed (N = 63)		2021-23 (N = 63)	
	N	%	N	%	N	%
Pristine/semi-natural	17	21.3	12	19.0	13	20.6
Predominantly unmodified	22	27.5	17	27.0	13	20.6
Obviously modified	10	12.5	7	11.1	18	28.6
Significantly modified	19	23.8	17	27.0	10	15.9
Severely modified	12	15.0	10	15.9	9	14.3

Table 3-2 National Trend analysis for streamside indicators for aggregate asset classes across Wales. Mean, minimum confidence interval (CI) and maximum CI, mean change and p-values were extracted from models for periods 2013-16 and 2021-23. Insufficient data was available for reporting on National Trends for mountain moor and heath.

Habitat	Indicator	2013-16			2021-23			Trend	
		Mean	lower CI	upper CI	Mean	lower CI	upper CI	Mean Change	P value
Wales	Habitat Modification Score	213.73	136.28	335.18	178.49	112.69	282.72	-35.23	0.06
	Habitat Modification Score - Poaching	14.61	10.58	20.18	12.94	9.04	18.52	-1.67	0.49
Enclosed Farmland	Habitat Modification Score	603.34	377.78	963.57	512.92	314.77	835.82	-90.42	0.48
	Habitat Modification Score - Poaching	22.14	15.14	32.37	21.14	13.99	31.95	-1.00	0.85
Semi-natural Grassland and Fen	Habitat Modification Score	408.46	211.16	790.09	328.87	159.59	677.71	-79.58	0.54
	Habitat Modification Score - Poaching	18.13	11.30	29.08	15.18	8.89	25.93	-2.95	0.56
Woodland	Habitat Modification Score	418.42	200.17	874.66	292	123.33	691.35	-126.43	0.53
	Habitat Modification Score - Poaching	11.93	5.54	25.71	9.93	4.00	24.61	-2.01	0.76

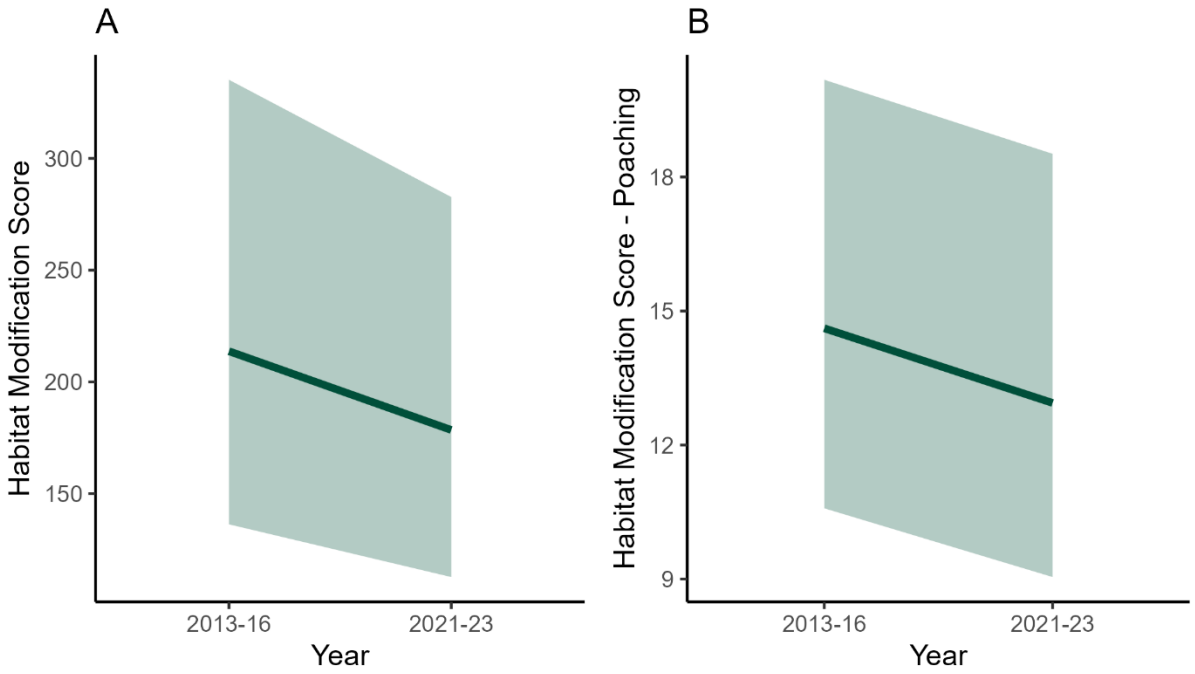

Figure 3-7 Trend in A) Habitat Modification Score and B) Habitat Modification Score - Poaching between 2013-16 and 2021-23 from nationally representative survey squares.

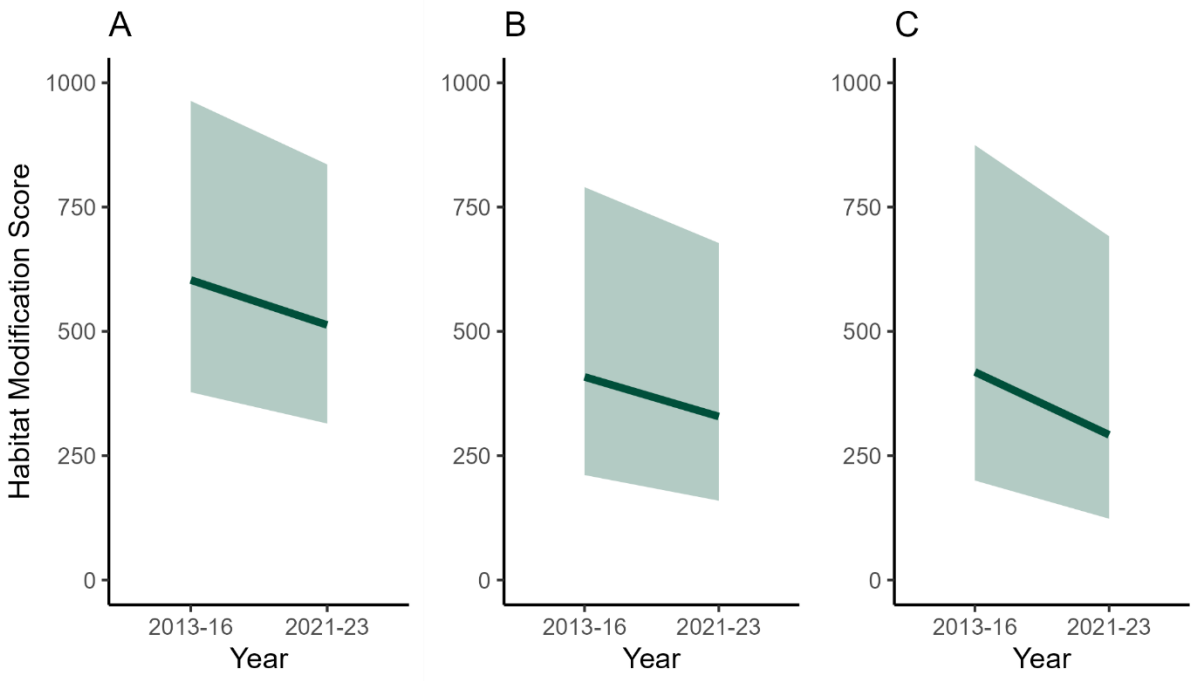

Figure 3-8 Trend in Habitat Modification Score between 2013-16 and 2021-23 from nationally representative survey squares, weighted by Asset Class cover for A) Enclosed Farmland, B) Semi-natural Grassland and Fen, C) Woodland.

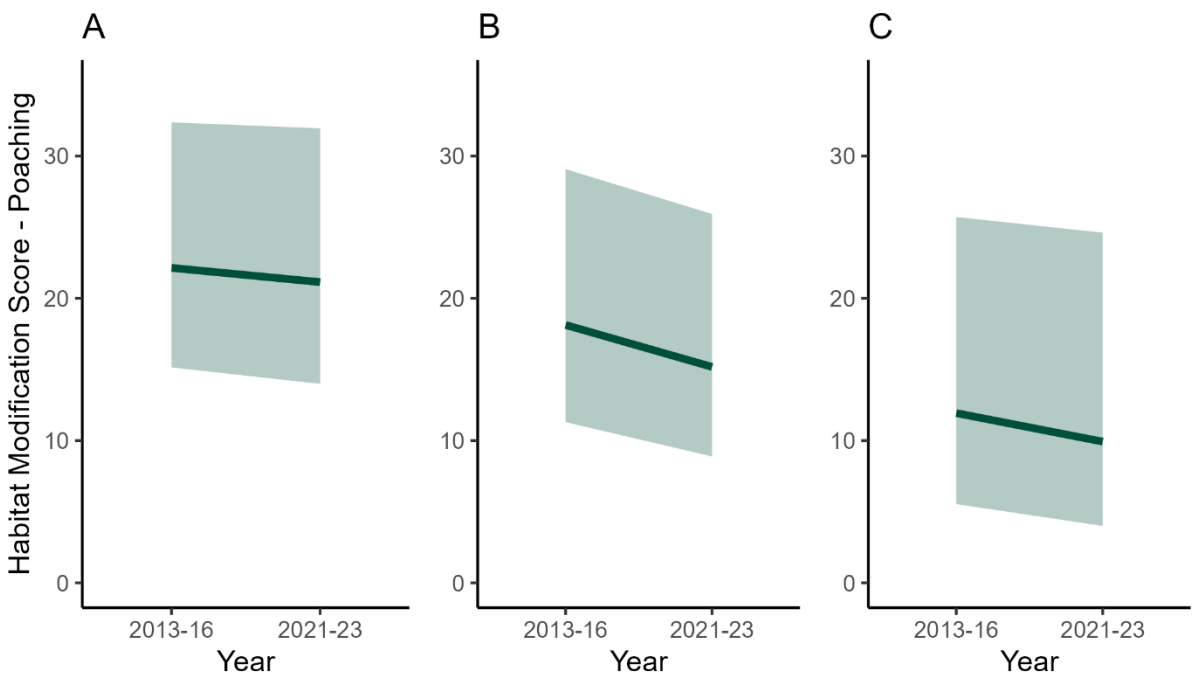

Figure 3-9 Trend in Habitat Modification Score - Poaching between 2013-16 and 2021-23 from nationally representative survey squares, weighted by Asset Class cover for A) Enclosed Farmland, B) Semi-natural Grassland and Fen, C) Woodland.

Table 3-3 Types of stream modification and presence in Streamsides for 2013-2016 and 2021 – 2023, for Nationally Representative squares within all sites surveyed in 2013-16 and for repeat survey sites.

Modification	2013-2016		2021-2023	
	Presence	Presence (%)	Presence	Presence (%)
Poaching	40	63.5	38	60.3
Culverts	30	47.6	29	46.0
Bank bed resectioning	15	23.8	15	23.8
Bank bed reinforcement	12	19.0	7	11.1
Bridges	8	12.7	7	11.1
Fords	7	11.1	9	14.3
Wiers, dams and sluices	7	11.1	5	7.9
Outfalls and deflectors	5	7.9	2	3.2
Berms and embankments	4	6.3	2	3.2

Table 3-4 Types and mean extent per site of erosion features on stream banks surveyed in all survey squares.

Process type	Process	Presence	Presence (%)	Affected bank length (%)	Features per site	Maximum recorded features per site
Artificial	Poaching	42	64.6	4.9	3.7	17
	Access	10	15.4	0.8	1.1	2
	Ford	1	1.5	0.8	1.0	1
	Footpaths	0	0.0	0.0	0.0	0
Fluvial	Below structure	43	66.2	4.0	2.8	18
	Full bank scour	26	40.0	3.3	2.1	9
	Stable cliff	25	38.5	7.5	1.8	5
	Bed scour	19	29.2	0.4	1.2	2
Biological	Tree fall	4	6.2	0.5	1.0	1
	Burrowing	3	4.6	0.1	1.0	1
Other	Tributary	43	66.2	0.3	1.6	6
	Potential non-field runoff	8	12.3	2.5	1.0	1
	Potential field runoff	5	7.7	4.3	3.6	9

3.7 Glastir Analysis

Here we provide the results for the Glastir analysis in streamsides indicators for All Wales and for asset classes, where possible. When considering effects of Glastir in the context of specific asset in steamsides, a weighting term was used in the model that is proportional to the percentage of the area surrounding the transect in the focal asset class. Streamsides for which the asset class is not present are excluded from the model. Glastir bundles and survey (2013-16 or 2021-23) used in the models, additional terms were included to control for the different landscape and historical contexts across sites. These are:

- Presence of historic agri-environment scheme options in the past (see Section 2.5 Glastir data)
- Land use intensity in the surrounding area. In this context, this was captured through the percentage of the 100m buffer surrounding the surveyed streamside within the Enclosed Farmland asset class. This was not used in models where enclosed farmland cover was included in the model as a weighting factor.

The modelling approach used here is described in greater detail in Jarvis et al. (2025), including a description of model structures. Results tables for all analyses are provided below. For a summary of Glastir analysis results please see Section 6.2.6 of Emmett et al. (2025).

Glastir analysis was only performed for the poaching sub-indicator of the habitat modification score, as other aspects of the indicator are not expected to respond to Glastir

management. When implementing asset-class weighted models, Glastir options were only considered present where they co-occurred with that asset class.

3.7.1.1 Poaching - Habitat Modification Sub-Score

Table 3-5 Glastir analysis for streamside indicators for All Wales and asset classes. Glastir management bundles assessed for effects on indictors are shown, but greyed out where data did not allow for analysis. Context effect was tested using information related to participation in historic agri-environment schemes and where appropriate, Enclosed farmland cover within a 100m buffer of the streamside.

Habitat	Indicator	Glastir Option Bundle	Glastir Effect	P value	Context effect on change
All Wales	Habitat modification score: Poaching	All Glastir	1.47	0.82	No
		Grazing inputs	5.54	0.27	No [1]
		Habitat management	1.80	0.74	No [1]
		Wildlife Corridor management	-6.04	0.45	No [1]
		Woodland management	-3.51	0.64	No [1]
Enclosed Farmland	Habitat modification score: Poaching	All Glastir	-1.53	0.89	No
		Grazing inputs	2.87	0.83	No
		Habitat management	4.91	0.75	No
		Wildlife Corridor management	-8.16	0.63	No
		Woodland management	13.03	0.51	No
Semi-natural grassland and fen	Habitat modification score: Poaching	All Glastir	10.96	0.25	No
		Grazing inputs	5.88	0.62	No
		Habitat management	6.28	0.52	No
		Wildlife Corridor management			
		Woodland management			

[1] This differs to the context effect reported in the main text. In the main text we included effects of context variables on mean scores across both time periods (not included here) as well as effects of context variables on the rate of change.

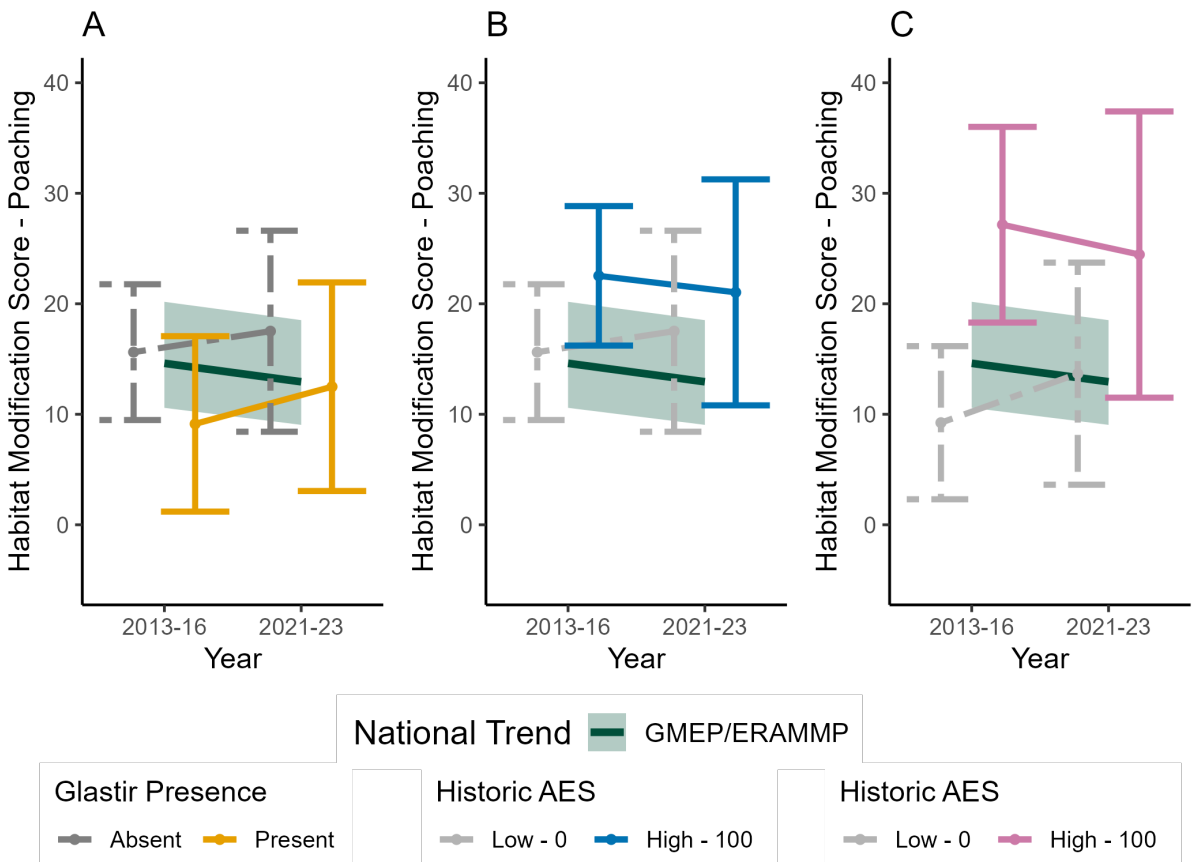

Figure 3-10 Trend in Habitat Modification Score - Poaching between 2013-16 and 2021-23 for All Wales showing both National Trends and effect of uptake of A) All Glastir Options, B) Historic Agri-Environment Scheme Option uptake when low (0%) or high (100%), C) Enclosed Farmland Cover within the Catchment when low (0%) or high (100%).

4 PONDS

The survey of ponds is based on ponds that fall within the 300 1km squares surveyed in GMEP, and the subset of 224 squares resurveyed in the ERAMMP. The selection of sites for resurvey is described in Alison et al. (2021) and summarised in Jarvis et al. (2025). In all survey years, ponds were surveyed in each square that contained a suitable pond. In the original survey (2013-16) where squares contained multiple suitable ponds, one was chosen at random and that pond was subsequently revisited.

The field survey of ponds contains a single workflow in which macroinvertebrates, water chemistry, pond macrophytes and environmental metadata are collected (Figure 4-1):

A full description of the field survey methods used is provided in Scarlett et al. (2025). Macro-invertebrate identification and derived indicator calculation were performed by the Pond Habitat Trust. Data cleaning and integrity checks are performed by UKCEH. In all cases, variables were calculated using consistent methods for all surveyed time periods.

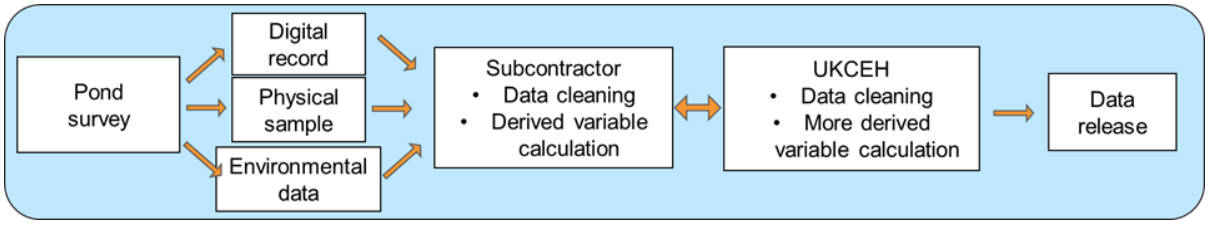

Figure 4-1 Data collection and processing pathways for data collected within the ponds monitoring in the ERAMMP and GMEP monitoring programs.

4.1 Dataset Overview

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 (Nationally representative sites) were revisited but only 78 of the Targeted squares (which targeted areas with high Glastir uptake), due to cost limitations. However, not all squares contain relevant features for ponds. Additional information can be found in Jarvis et al. (2025).

Raw data coverage across all years of the first survey (GMEP, 2013-16) and recent resurvey (ERAMMP, 2021-23) is provided in Table 4-1. Each site is surveyed once per survey cycle.

Table 4-1 Squares surveyed during GMEP and ERAMMP National Field Survey of ponds

Data	GMEP (2013-16)				ERAMMP (2021-23)		
	2013	2014	2015	2016	2021	2022	2023
Pond Survey	28	38	31	18	38	5	28

For all freshwater survey sites, the area of influence around a pond is defined by a 100m buffer around the sample site.

4.2 Data Quality Assurance

All data used in these analyses have been subject to quality assurance. This includes:

- Manual inspection and verification of reported survey locations against historic reports and photographs.
- Inspection of all raw data and derived variables against known ecological limits and historic reporting
- Confirmation of data continuity and integrity across survey strands
- Independent quality assurance of taxonomic ID carried out by subcontractors.
- Inspection of taxonomic data for errors and synonyms

In addition, surveyor training and procedures are reviewed on an annual basis. Reporting methods and methods used in the derivation of all reporting variables are reviewed for each reporting cycle.

4.3 Derived Indicators

The following indicators and metrics are reported on in ERAMMP report XX using the pond dataset for status and change in condition over both survey periods:

- Pond Biotic Quality (Index of Biotic Integrity)
- Macrophyte richness (Sub-indicator of Index of Biotic Integrity)
- Uncommon macrophyte index (Sub-indicator of Index of Biotic Integrity)
- Macrophyte-derived nutrient condition (Sub-indicator of Index of Biotic Integrity)
- Macro-invertebrate derived water quality (Sub-indicator of Index of Biotic Integrity)
- Odonata and Megaloptera richness (Sub-indicator of Index of Biotic Integrity)
- Coleoptera richness (Sub-indicator of Index of Biotic Integrity)
- Presence of invasive plant taxa
- Presence and abundance of invasive macro-invertebrate taxa

4.3.1.1 Pond Biotic Integrity

All indicators of Biotic Integrity are derived using the Predictive System for Multimetrics (PSYM) (Howard, 2002). A description of the meaning of these indicators in a pond quality context is provided in Section 6.3.2 of Emmett et al. (2025).

4.3.1.2 Invasive species

The plant and invertebrate species present in pond samples were checked against a list of freshwater invasive species of concern to Wales (NBN Atlas, 2019) which identified 162 aquatic alien species from the 348 invasive non-native species currently of most interest to

Wales and taxa relevant to UK Biodiversity targets B6 (Harrower et al., 2023). The level of Invasive risk category was derived from the UKTAG impact classification working paper (WFD-UKTAG, 2015).

We quantified the presence of invasive macrophytes and presence and abundance of invasive macro-invertebrates in Ponds. Metrics report are:

- Number of ponds with invasive taxa
- Percentage of ponds with invasive taxa
- Average taxonomic richness per pond
- Invasive taxa (mean % of taxa per pond)
- Maximum prevalence of invasive taxa recorded (% taxa)
- Invasive macro-invertebrate abundance (mean % abundance)
- Taxa number - total count of ponds where the taxa are present
- Taxa abundance - total abundance of taxa across all the ponds where the taxa are present

4.3.1.3 Dry ponds

Ponds reported as dry were dry at the time of the fields survey visit. This can be naturally occurring, particularly during the summer months and is not in and of itself a cause for concern. However, trends in the frequency of dry ponds may be indicative of changing pressures on pond systems.

4.4 Habitat Classification

Habitat cover was assessed for a 100m radius around the recorded sampling point for ponds (Levy, et al., 2024) and for 2021-23 using a 2021 product (Marston, Rowland, O'Neil, & Morton, 2022), derived using identical methods. Aggregated broad habitats were subsequently used in all assessments of catchment habitat cover.

For all subsequent analysis where habitat cover was considered, we used the habitat cover at the beginning of the survey period corresponding to the 2010 Land Cover Map.

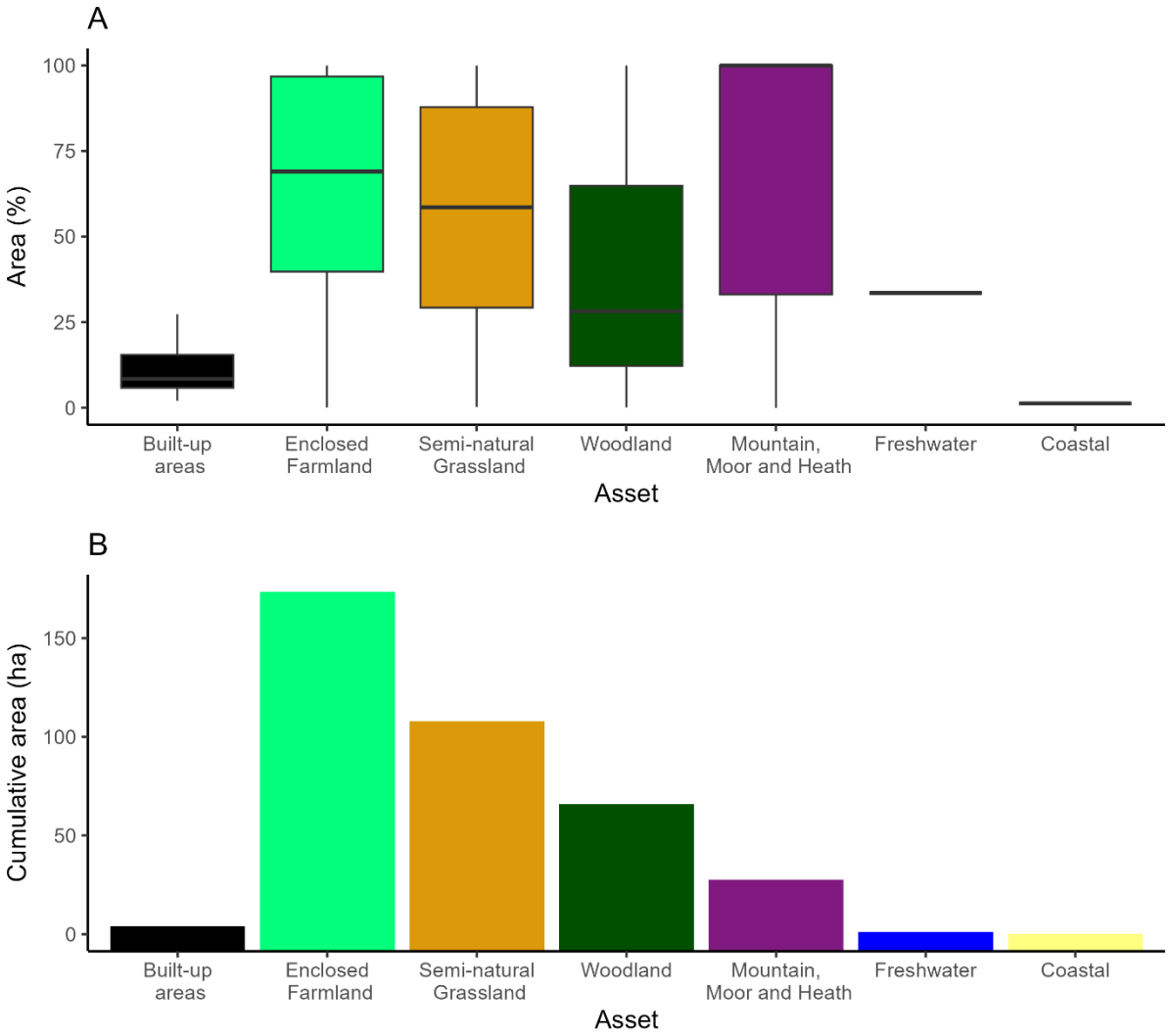

Figure 4-2 A) The distribution of detected asset class within a 100m radius of all Pond monitoring sites established in 2013-16, as a percentage of the area across different habitat asset classes. The horizontal lines indicate the midpoint, the boxes indicate where the mid 50% of all values sit and the vertical lines represent the full range of values observed. B) Cumulative area of asset classes represented within a 100m range of all Pond monitoring sites established in 2013-16.

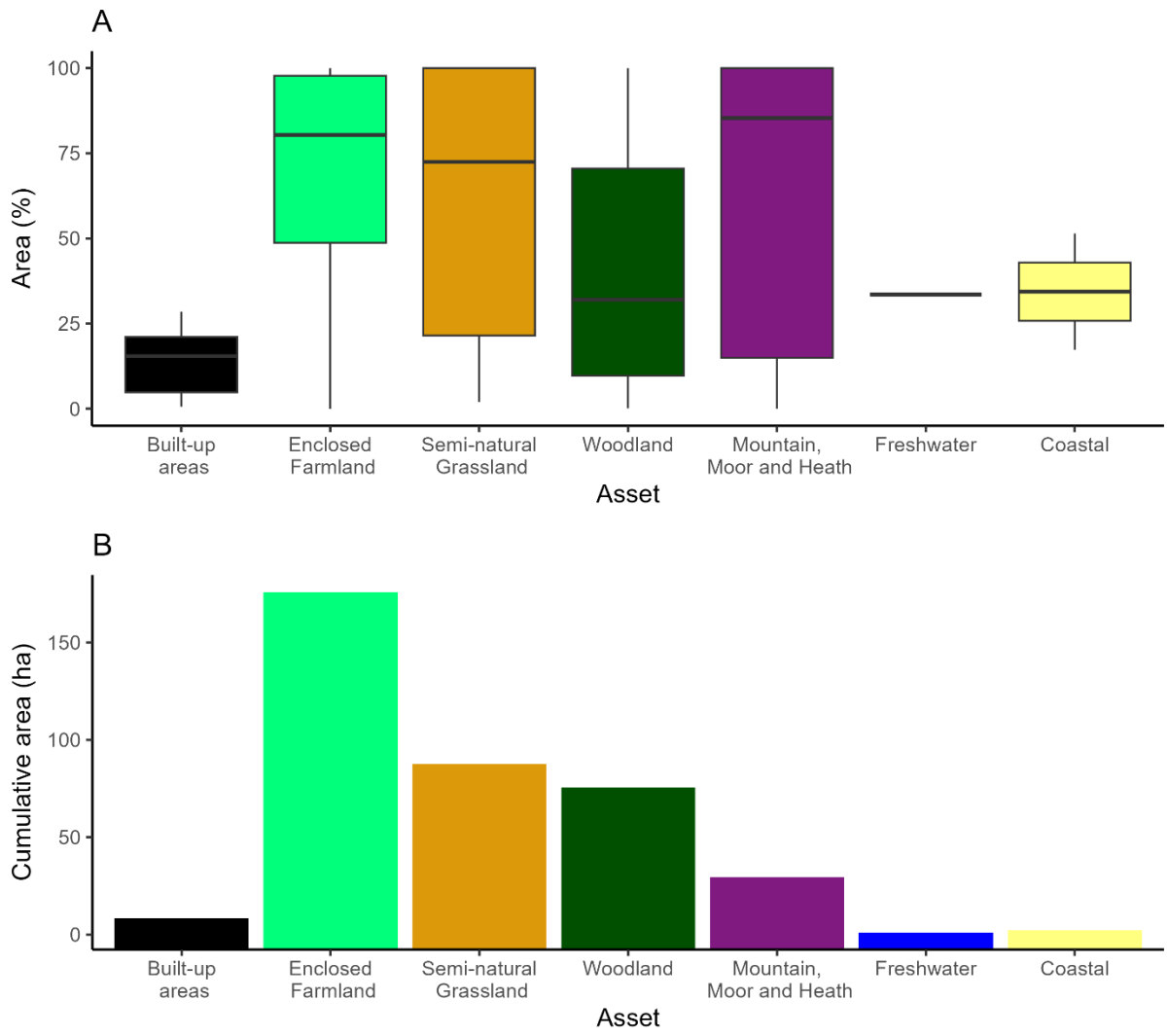

Figure 4-3 A) The distribution of detected asset class within a 100m radius of all Pond monitoring sites established in 2021-23, as a percentage of the area across different habitat asset classes. The horizontal lines indicate the midpoint, the boxes indicate where the mid 50% of all values sit and the vertical lines represent the full range of values observed. B) Cumulative area of asset classes represented within a 100m range of all Pond monitoring sites established in 2021-23.

4.5 Glastir Data

Information of Glastir option uptake within 100m of pond surveys was extracted to enable an analysis of the effects of Glastir management on our indicators over time. Glastir Options have been aggregated in to bundles of options with similar managements and intended outcomes to facilitate this analysis, and these bundles are described in more detail in Jarvis et al. (2025). Analyses of Glastir Option effects were only performed where 1) there was an underpinning logic chain support a link between Glastir managements and the measured indicator, and 2) there was sufficient data coverage and Glastir Option uptake.

Glastir coverage for ponds was defined for each Glastir Option bundle and for Glastir as a whole. In each case, we extracted all contributing actions that occurred within a 100m buffer of the sample site for each year. Glastir was defined as present if any action within the relevant bundle was applied in the relevant period. For data collected in 2013-16 we

considered years from the start of Glastir (2012) up to and including the sampling year. For data collected in 2021-23 we considered years after the previous sample was collected, up to and including the current year of sample collection. If no previous sample was collected, we assumed a baseline of 2015 (the mean sampling date from 2013-16).

Coverage for historic agri-environment schemes of Tir Gofal and Tir Cynnal was also extracted using the same approach, where historic management was present if either Tir Gofal and Tir Cynnal occurred in any prior year.

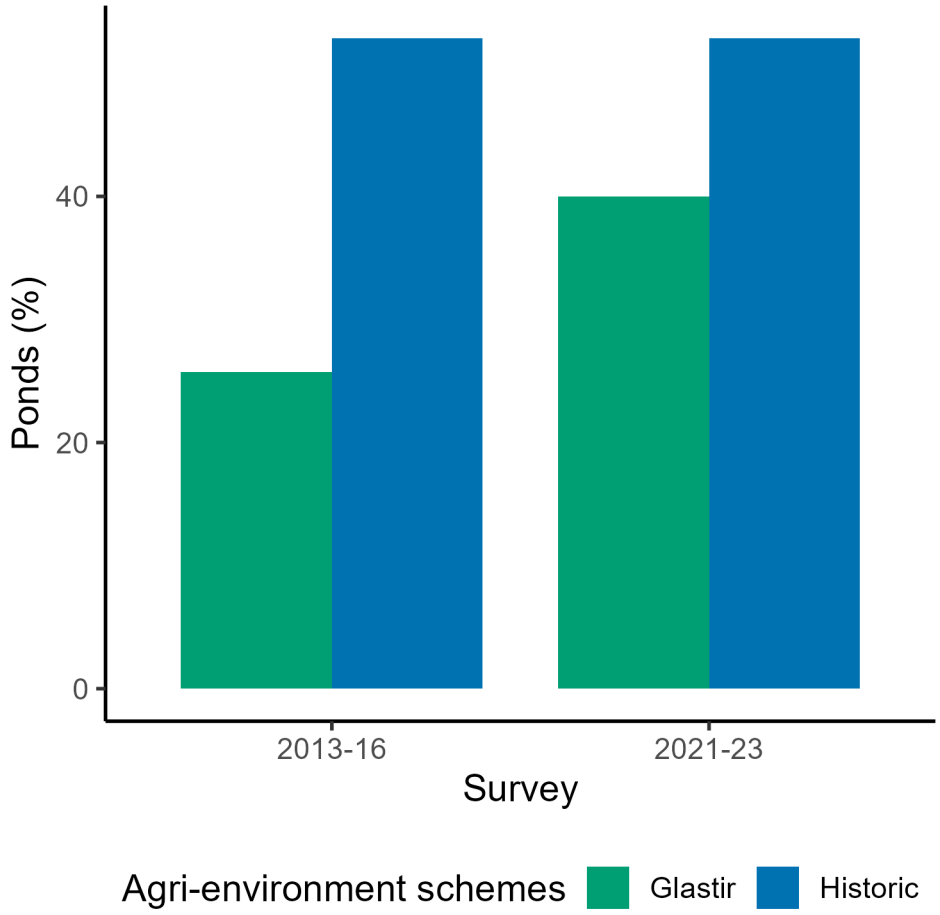

Figure 4-4 Glastir option and historic AES (Tir Gofal and Tir Cynnal) presence within 100m of Ponds during the 2013-16 and 2021-23 surveys, for Ponds surveyed in both time periods.

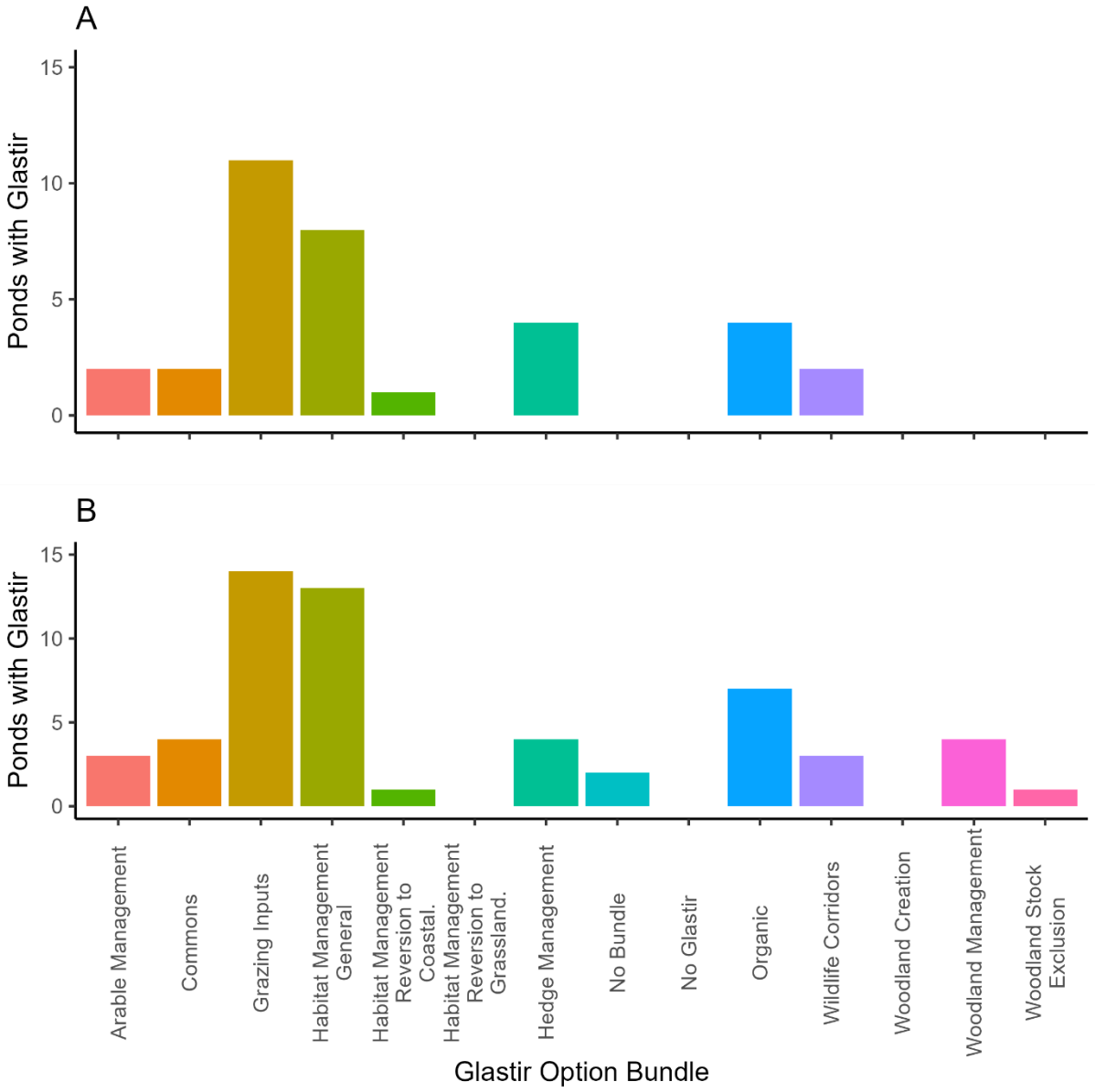

Figure 4-5 The number of surveyed ponds with Glastir options present, by bundle within the A)2013-16 and B)2021-23, for the subset of sites that were surveyed in both periods.

4.6 National Trend Analysis

Here we provide the results for the National trends in pond indicators for All Wales and for asset classes, where possible. When considering National Trends for specific asset classes a weighting term was used in the model that is proportional to the percentage of the surrounding area (100m radius) in the focal asset class. Ponds for which the asset class is not present are excluded from the model. The modelling approach used here is described in greater detail in Jarvis et al. (2025).

Results tables for all analyses are provided below. For a summary of National Trend results please see Section 6.3.5 of Emmett et al. (2025).

4.6.1.1 Pond biotic integrity

Table 4-2 Presence and relative abundance of ponds in each category of pond condition based on the Pond Biotic Quality Indicator for nationally representative sites, all where N is the number of ponds. Separate counts are provided for all nationally representative sites surveyed in 2013-16 and the subset of those sites in the resurveyed population, to facilitate comparison with results form 2021-23

PSYM Class	2013-16 (N = 59)		2013-16 Resurveyed (N = 41)		2021-23 (N = 41)	
	N	%	N	%	N	%
Good	7	11.9	5	12.2	4	9.8
Moderate	32	54.2	21	51.2	18	43.9
Poor	16	27.1	12	29.3	16	39.0
Very Poor	4	6.8	3	7.3	3	7.3

Table 4-3 National Trend analysis for pond indicators for aggregate asset classes across Wales. Mean, minimum confidence interval (CI) and maximum CI, mean change and p-values were extracted from models for periods 2013-16 and 2021-23.

Habitat	Indicator	2013-16			2021-23			Trend	
		Mean	lower CI	upper CI	Mean	lower CI	upper CI	Mean Change	P value
Wales	Pond Biotic Quality	53.57	48.79	58.35	52.45	47.21	57.69	-1.12	0.64
	Macrophyte richness	0.55	0.48	0.61	0.62	0.54	0.69	0.07	0.05
	Uncommon macrophyte index	0.28	0.20	0.36	0.33	0.24	0.43	0.05	0.30
	Macrophyte-derived nutrient condition[1]	1.19	1.08	1.29	1.07	0.95	1.19	-0.12	0.09
	Macro-invertebrate derived water quality	0.85	0.82	0.87	0.83	0.80	0.87	-0.01	0.39
	Odonata & Megaloptera richness	0.61	0.47	0.75	0.53	0.36	0.70	-0.08	0.43
	Coleoptera richness	0.93	0.86	1.00	0.71	0.62	0.80	-0.22	<0.01
Enclosed Farmland	Pond Biotic Quality	51.37	45.13	57.6	49.37	41.85	56.89	-1.99	0.63
	Macrophyte richness	0.52	0.44	0.60	0.60	0.50	0.70	0.08	0.15
	Uncommon macrophyte index	0.27	0.17	0.38	0.28	0.15	0.42	0.01	0.92
	Macrophyte-derived nutrient condition[1]	1.31	1.17	1.46	1.12	0.94	1.30	-0.19	0.11
	Macro-invertebrate derived water quality	0.82	0.79	0.85	0.84	0.80	0.88	0.02	0.44
	Odonata & Megaloptera richness	0.54	0.38	0.70	0.41	0.19	0.62	-0.13	0.33

	Coleoptera richness	0.93	0.84	1.03	0.68	0.55	0.81	-0.25	<0.01
Semi-Natural and Improved Woodland	Pond Biotic Quality	55.47	45.88	67.08	52.21	42.67	63.88	-3.27	0.62
	Macrophyte richness	0.63	0.47	0.80	0.70	0.52	0.88	0.07	0.56
	Uncommon macrophyte index	0.27	0.10	0.44	0.41	0.23	0.60	0.14	0.27
	Macrophyte-derived nutrient condition[1]	1.08	0.83	1.32	1.01	0.74	1.28	-0.07	0.71
	Macro-invertebrate derived water quality	0.90	0.84	0.96	0.84	0.77	0.91	-0.06	0.15
	Odonata & Megaloptera richness	0.76	0.39	1.12	0.70	0.26	1.14	-0.06	0.84
	Coleoptera richness	0.95	0.80	1.10	0.72	0.54	0.90	-0.23	0.05
Woodland	Pond Biotic Quality	56.78	47.7	67.59	55.75	44.83	69.33	-1.03	0.88
	Macrophyte richness	0.52	0.40	0.65	0.57	0.43	0.71	0.05	0.64
	Uncommon macrophyte index	0.32	0.14	0.51	0.30	0.09	0.50	-0.02	0.86
	Macrophyte-derived nutrient condition[1]	1.04	0.87	1.20	0.99	0.82	1.16	-0.05	0.68
	Macro-invertebrate derived water quality	0.85	0.80	0.91	0.84	0.78	0.90	-0.01	0.78
	Odonata & Megaloptera richness	0.58	0.34	0.82	0.53	0.26	0.80	-0.05	0.78
	Coleoptera richness	0.90	0.74	1.05	0.78	0.6	0.96	-0.11	0.35
Mountain Moor and Heath	Pond Biotic Quality								
	Macrophyte richness								
	Uncommon macrophyte index								
	Macrophyte-derived nutrient condition[1]								
	Macro-invertebrate derived water quality								
	Odonata & Megaloptera richness								
	Coleoptera richness								

[1] An increase above 1 indicates more eutrophic conditions and below 1 indicates dystrophic conditions, both considered a decrease in pond quality.

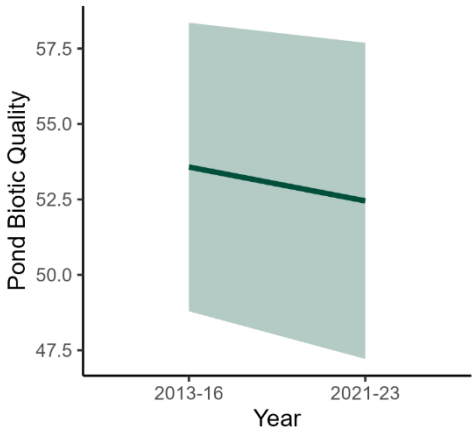

Figure 4-6 Trend in Pond Biotic Quality between 2013-16 and 2021-23 from nationally representative survey squares.

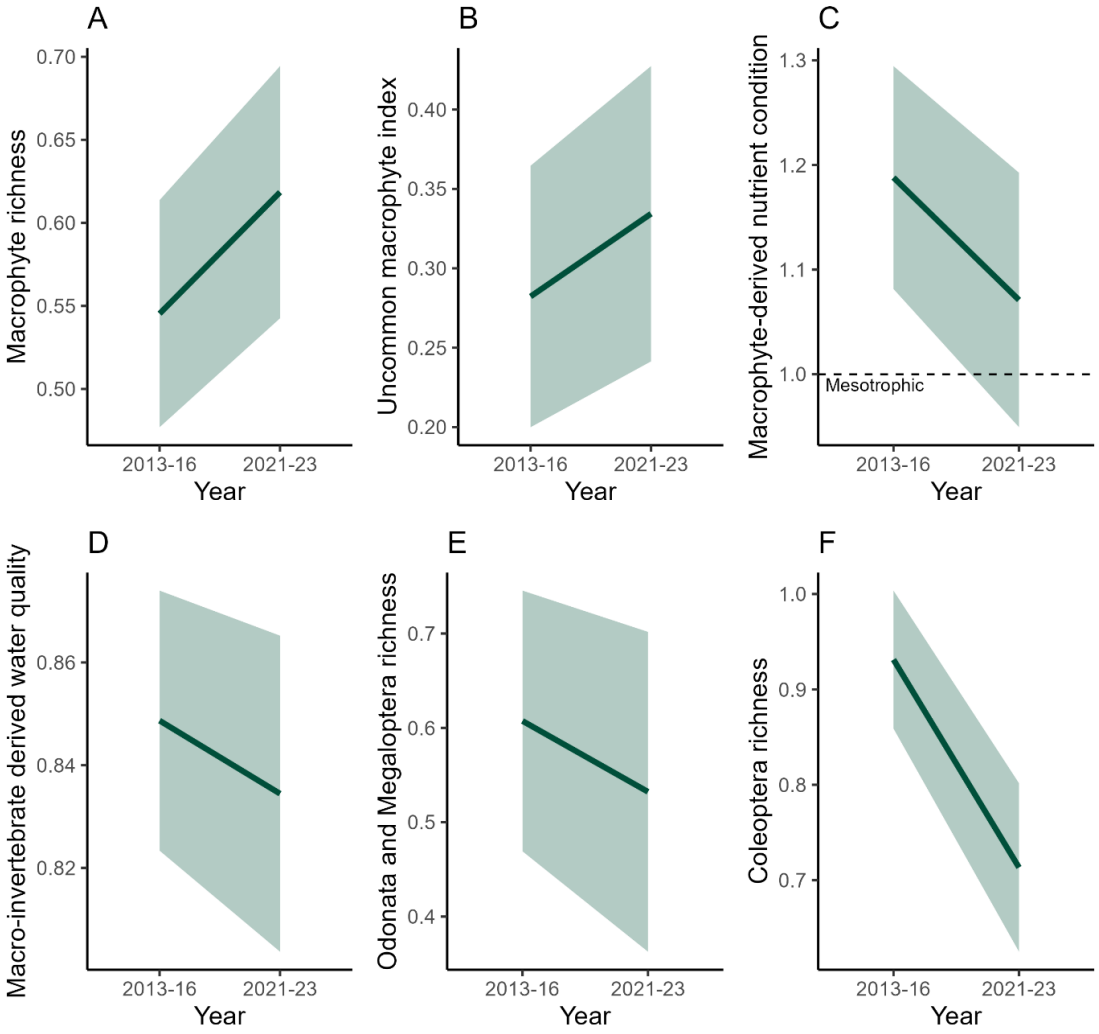

Figure 4-7 Trend in Pond A) Macrophyte richness, B) Uncommon macrophyte index,C) Macrophyte-derived nutrient condition, D) Macroinvertebrate derived water quality, E) Odonata and Megaloptera richness and F) Coleoptera richness between 2013-16 and 2021-23 from Nationally Representative squares.

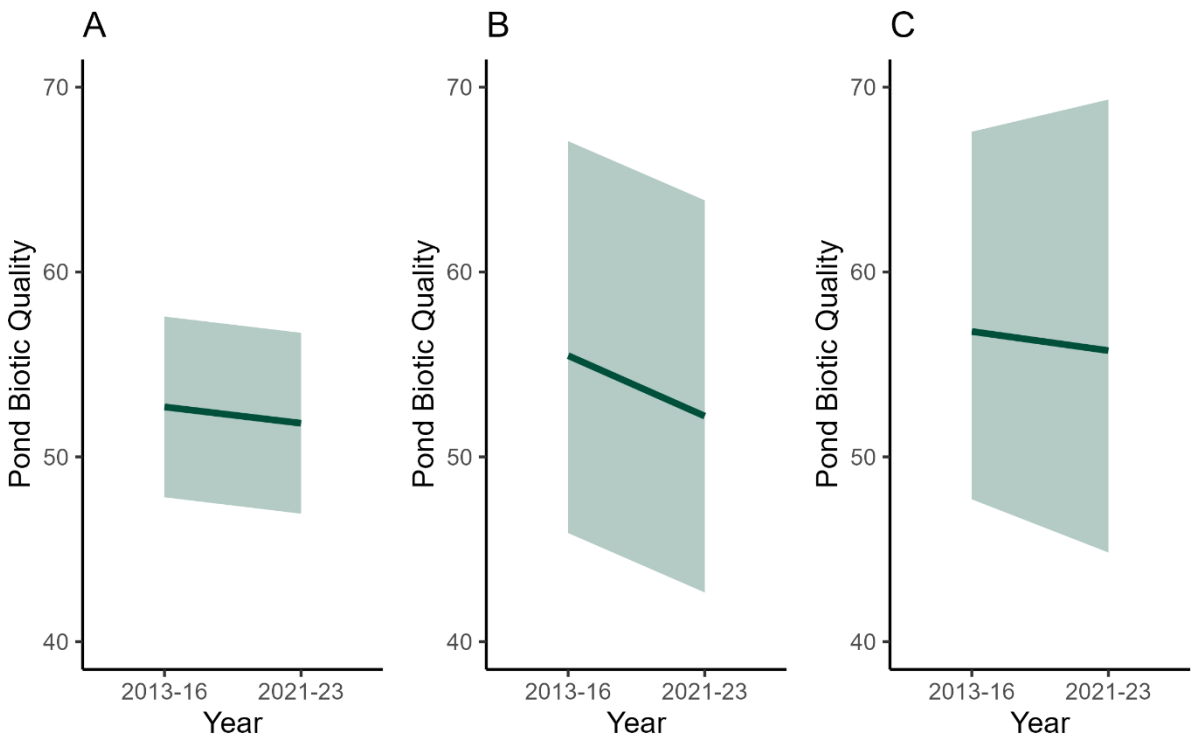

Figure 4-8 Trend in Pond Biotic Quality between 2013-16 and 2021-23 from nationally representative survey squares withed by Asset class coverage for A) Enclosed Farmland, B) Semi-natural Grassland and fen and C) Woodland.

4.6.1.2 Invasive Species

Table 4-4 National Trend analysis for pond invasive invertebrate indicators. Absolute count or percentage of ponds in the population for that indicator. For all survey squares in 2013-2016 and for the Nationally Representative sites that have been resurveyed in 2021-2023.

	2013-2016 (N =114)	2013-2016 resurveyed (N =35)	2021-2023 (N=35)
Number of ponds with invasive taxa	54	20	20
Ponds with invasive taxa (%)	47.4	57.1	57.1
Mean number of all taxa	39.5	41.8	41.2
Mean Invasive taxa present (% per site)	1.8	1.9	2.3
Maximum invasive taxa present (%)	12	9	9
Mean abundance of invertebrates	2694.1	3096.4	2089.8
Mean abundance of invasive invertebrates	243.2	468.4	287.3
Mean invasive individuals present (%)	6.8	10.5	8.5

Table 4-5 National Trend analysis for pond invasive invertebrate species. Absolute count of ponds where the species is present and total abundance across all samples in the population for that species. Population is the Nationally Representative sites that have been resurveyed in 2021-2023.

Species	2013-2016 Resurveyed (N =35)		2021-2023 (N =35)	
	Number	Abundance	Number	Abundance
Potamopyrgus antipodarum	12	8686	10	4469
Crangonyx pseudogracilis	11	3157	12	4213
Physella sp (acuta/gyrina)	9	3918	5	850
Ferrissia wautieri	1	14	6	47
Menetus dilatatus	1	620	2	425
Girardia tigrina	0	0	2	49
Proasellus coxalis	0	0	1	1

Table 4-6 National Trend analysis for pond invasive plant indicators. Absolute count or percentage of ponds in the population for that indicator. For all survey squares in 2013-2016 and for the Nationally Representative sites that have been resurveyed in 2021-2023.

	2013-2016 Resurveyed (N =43)	2021-2023 (N =43)
Number of ponds with invasive plants	4	10
Ponds with invasive plants (%)	9.3	23.3
Mean number of all taxa	13.0	14.7
Mean invasive taxa present (%)	0.7	1.6
Maximum invasive taxa present (%)	11.0	12.0

*Table 4-7 National Trend analysis for pond invasive **plant** species. Absolute count of ponds where the species is present and total abundance across all samples in the population for that species. Population is the Nationally Representative sites that have been resurveyed in 2021-2023.*

Species	Ponds with species present	
Species	2013-2016 resurvey (N=43)	2021-2023 (N=43)
Lagarosiphon major	2	2
Elodea canadensis	1	2
Impatiens glandulifera	2	4
Lemna minuta	0	2
Crassula helmsii	0	1

4.7 Glastir Analysis

Here we provide the results for the Glastir analysis in pond indicators for All Wales and for asset classes, where possible. When considering effects of Glastir in the context of a

specific asset, a weighting term was used in the model that is proportional to the percentage the surrounding area in the focal asset class. Ponds for which the asset class is not present are excluded from the model. Glastir bundles and survey (2013-16 or 2021-23) were used in the models as fixed effects, additional terms were included to control for the different landscape and historical contexts across sites. These are:

- Presence of historic agri-environment scheme management in the past (see Section 4.5 Glastir data)
- Land use intensity in the surrounding area. In this context, this was captured through the percentage of a 100m buffer within the Enclosed Farmland asset class.

When implementing asset-class weighted models, Glastir options were only considered present where they co-occurred with that asset class. The modelling approach used here is described in greater detail in Jarvis et al. (2025), including a description of model structures. Results tables for all analyses are provided below. For a summary of Glastir analysis results please see Section 6.3.6 of Emmett et al. (2025).

4.7.1.1 Pond Biotic Integrity

Table 4-8 Glastir analysis pond indicators for All Wales and asset classes. Glastir management bundles assessed for effects on indictors are shown, but greyed out where data did not allow for analysis. Context effect was tested using information related to participation in historic agri-environment schemes and enclosed farmland cover.

Habitat	Indicator	Glastir bundle	Trend difference	P value	Context Effect on Trend
All Wales	Pond Biotic Quality	All Glastir	4.52	0.26	No
	Pond Biotic Quality	Grazing Inputs	5.59	0.25	No
	Pond Biotic Quality	Habitat management	4.49	0.39	No
	Macrophyte richness	Grazing Inputs	0.01	0.87	No
	Macrophyte richness	Habitat management	0.03	0.72	No
	Uncommon macrophyte index	Grazing Inputs	0.05	0.85	No
	Uncommon macrophyte index	Habitat management	0.07	0.21	No
	Macrophyte-derived nutrient condition [2]	Grazing Inputs	0.05	0.69	No [1]
	Macrophyte-derived nutrient condition [2]	Habitat management	0.07	0.61	No [1]
	Macro-invertebrate derived water quality	Grazing Inputs	0.02	0.62	Yes
	Macro-invertebrate derived water quality	Habitat management	0.04	0.34	Yes
	Odonata and Megaloptera richness	Grazing Inputs	0.15	0.45	No
	Odonata and Megaloptera richness	Habitat management	0.19	0.34	No
	Coleoptera richness	Grazing Inputs	0.10	0.36	No[1]
	Coleoptera richness	Habitat management	-0.01	0.92	No[1]
Enclosed Farmland	Pond Biotic Quality	All Glastir	10.14	0.18	No
	Pond Biotic Quality	Grazing Inputs	8.38	0.38	No
	Pond Biotic Quality	Habitat management	10.77	0.34	No
	Macrophyte richness	Grazing Inputs	0.01	0.91	No

	Macrophyte richness	Habitat management	0.22	0.16	No
	Uncommon macrophyte index	Grazing Inputs	0.16	0.45	No
	Uncommon macrophyte index	Habitat management	0.16	0.62	No
	Macrophyte-derived nutrient condition [2]	Grazing Inputs	0.01	0.98	No
	Macrophyte-derived nutrient condition [2]	Habitat management	0.03	0.93	No
	Macro-invertebrate derived water quality	Grazing Inputs	0.07	0.21	No
	Macro-invertebrate derived water quality	Habitat management	0.01	0.83	No
	Odonata and Megaloptera richness	Grazing Inputs	0.41	0.20	No
	Odonata and Megaloptera richness	Habitat management	-0.01	0.97	No
	Coleoptera richness	Grazing Inputs	0.05	0.78	No
	Coleoptera richness	Habitat management	-0.01	0.96	No
Semi-natural grassland and fen	Pond Biotic Quality	All Glastir	6.32	0.53	No
	Pond Biotic Quality	Grazing Inputs	8.93	0.48	No
	Pond Biotic Quality	Habitat management	3.46	0.79	No
	Macrophyte richness	Grazing Inputs	0.10	0.67	No
	Macrophyte richness	Habitat management	0.08	0.74	No
	Uncommon macrophyte index	Grazing Inputs	-0.13	0.55	No
	Uncommon macrophyte index	Habitat management	0.05	0.39	No
	Macrophyte-derived nutrient condition [2]	Grazing Inputs	0.23	0.55	No
	Macrophyte-derived nutrient condition [2]	Habitat management	0.28	0.46	No
	Macro-invertebrate derived water quality	Grazing Inputs	0.05	0.56	No
	Macro-invertebrate derived water quality	Habitat management	0.00	0.98	No
	Odonata and Megaloptera richness	Grazing Inputs	0.37	0.48	No
	Odonata and Megaloptera richness	Habitat management	0.09	0.85	No
	Coleoptera richness	Grazing Inputs	0.23	0.35	No
	Coleoptera richness	Habitat management	0.07	0.76	No

[1] This differs to the context effect reported in the main text. In the main text we included effects of context variables on mean scores across both time periods (not included here) as well as effects of context variables on the rate of change.

[2] An increase above 1 indicates more eutrophic conditions and below 1 indicates dystrophic conditions, both considered a decrease in pond quality.

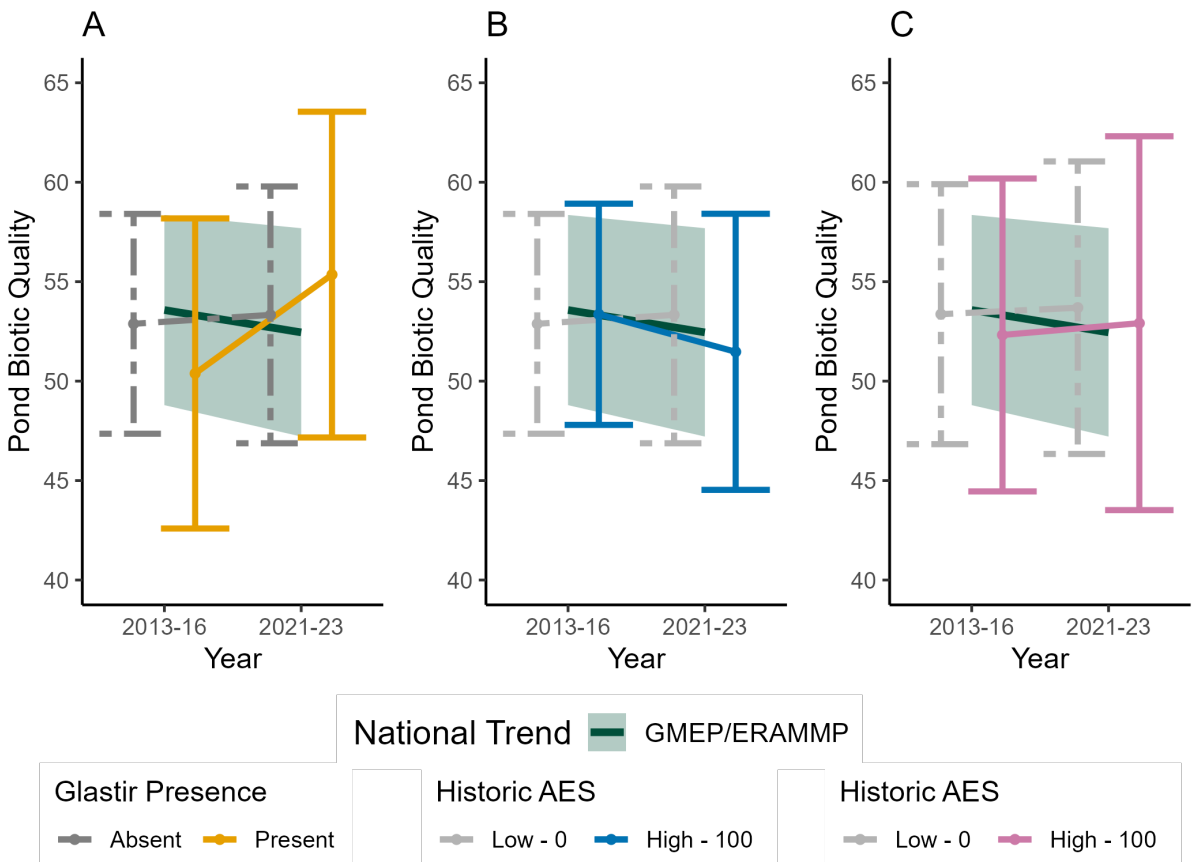

Figure 4-9 Trend in Pond Biotic Quality between 2013-16 and 2021-23 for All Wales showing both National Trends and effect of uptake of A) All Glastir Options, , B) Historic Agri-Environment Scheme Option uptake when low (0%) or high (100%), C) Enclosed Farmland Cover within the Catchment when low (0%) or high (100%).

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