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ERAMMP Report-99: Developing a New National Ecosystem Health and Resilience Indicator for Sustainable Land Management

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Abbreviations Used in this Report

BTO	British Trust for Ornithology
DECCA	Diversity, Extent, Condition, Connectivity, Adaptability
EO	Earth Observation
ERAMMP	Environment and Rural Affairs Monitoring & Modelling Programme
GMEP	Glastir Monitoring & Evaluation Programme
LCM	Land Cover Map
LW	Living Wales
NFS	National Field Survey
UKCEH	UK Centre for Ecology & Hydrology
WFG	Well-being of Future Generations
WG	Welsh Government

Contents

1 BACKGROUND

The aim of this work is to provide a potential indicator for reporting on the impact of Sustainable Land Management (SLM) actions with respect to Objective-3 'Maintain and enhance the health and resilience of ecosystems'. The Well-being of Future Generations (WFG) Act currently utilises Indicator-43 as the 'Area of Healthy Ecosystems within Wales'. However, this only currently reports on the extent of semi-natural vegetation, not its condition, diversity or connectivity which are all considered important in conferring ecosystem resilience. It was therefore not considered appropriate for SLM as the DECCA principle is followed in Wales to capture the complexity of characteristics which create a healthy and resilient ecosystem. DECCA stands for:

- **D** – diversity from genes to species, habitats and landscapes. Diversity supports the complexity of ecosystem functions and their interactions. Some diversity may not we desirable for example if arises from the presence of non-native or invasive species.
- **E** – extent or put simply how large an ecosystem is. Larger units can increase the capacity of an ecosystem to adapt, recover or resist disturbance Smaller units can be at greater risk from catastrophic events. However, some species specialise using small fragments of our highly modified landscape such as streamsides and field margins. Extent can then be considered as to the quantity of these smaller units in total across the landscape.
- **C** – condition can cover the status of both the biotic and abiotic components and agreed indicators are available for most of these components for terrestrial and freshwater systems.
- **C** – connectivity enables the movement of species across the landscape and is through to increase resilience as species can move to avoid stresses. There can be negative aspects of this for example in linking fast flows of water which generate floods across the landscape.
- **A** – adaptability describes how the elements above come together to create resilience. There is as yet no agreed approach for quantifying this in Wales or indeed for any nation of the UK.

As an alternative to the use of WFG Indicator-43, an approach is proposed which exploits the rich data captured by the ERAMMP programme National Field Survey (2013-16 and 2021-23) for diversity and condition measurements and indices and UKCEH's landcover mapping activities (2010 and 2021) recently reported in ERAMMP Report-105 (Emmett, et al., 2025); for extent and connectivity data.

2 DATA SOURCES

2.1 ERAMMP National Field Survey for diversity and condition

One element of the Environment and Rural Affairs Monitoring and Modelling Programme (ERAMMP) is the National Field Survey (NFS). This is a survey of 150 nationally representative 1km squares across Wales to report on national trends over time. The outcome of the most recent re-survey reporting change between 2013-16 and 2021-23 was reported in ERAMMP Report-105; Emmett et al, 2025.

In brief, within each NFS 1km square a wide range of measurements are taken covering

- the condition of soil
- the condition of small water bodies (i.e. headwaters and ponds),
- vegetation assessment from permanent quadrats covering both random locations and habitats of conservation interest,
- condition and extent of woodland, hedgerows and woody features including individual trees,
- abundance of different bird and pollinator species,
- condition of, and threats to, historic environment assets and condition of public rights of way.
- Landscape photography from 16 pre-set locations looking out from, and into, the 1km survey squares.

Results are reported by change detected for:

- 19 broad habitats and landscape features
- 5 resources (birds, pollinators, vegetation, soil and small freshwater bodies)
- climate change impacts
- cultural features
- landscape characteristics

For the purpose of this analysis for developing an ecosystem health and resilience indicator for SLM, a total of 58 indicators were selected covering our 5 resources. Some indicators are generic across multiple habitat types (e.g. positive plant indicators) some are specific to one type of habitat (e.g. *Sphagnum* cover). Selection excluded indices which summarised individual measurements to avoid duplication.

The direction of change of these 58 indicators for 19 habitat types and landscape features between 2013-16 and 2021-23 were then scored as either improved, no change or declined according to statistical analysis. The resulting database consisted of 251 individual measurements. These data are as reported in ERAMMP Report-105 for individual habitats, landscape features and is not repeated here but rather the summary provided of the findings by resource (Table 2-1).

Table 2-1 Number of measurements and indices across 5 resource categories from the ERAMMP NFS and their direction of change which were statistically significant.

Resource	Improved	No change	Declined
Birds	1	7	3
Pollinators	1	48	10
Vegetation (including woody features)	8	70	26
Soil	2	31	14
Freshwater	1	27	2
Total (%)	**13 (5%)**	**183 (73%)**	**55 (22%)**

Note that the number of measurements and indices across resources are highly variable and it should be noted further analysis of particularly species level responses is outstanding (most notably for birds). Also, whilst eDNA data is available for soil from the baseline NFS survey in 2013-16, this has not been used here as there are no agreed high level change metrics for national scale soil eDNA monitoring currently. No other genetic data is available to our knowledge which is nationally robust.

These measurements have been further categorised as to whether they relate to either condition or diversity (Table 2-2).

Table 2-2 Assignment of different resource measurements and indices from the ERAMMP NFS as being indicative of either condition or diversity. Note negative indices are indicated with an asterisk (*)

Condition	Diversity
Plant Common Standard Monitoring species (positive and negative*)	Plant species richness
Plant Invasive and Non-native species cover and richness*	Nectar plant species richness
Dwarf shrub cover	Plant Ancient Woodland Index
Sphagnum cover	Woody and ground flora species richness
Grass: Forb ratio*	Dwarf shrub species richness
Ellenberg indices for nutrients*, light and moisture	11 bird abundance indices
Hedge condition and management	5 pollinator abundance indices
All soil metrics	Freshwater macroinvertebrate index (O/E WHPT-ASPT)
Freshwater invertebrate indices (WHPT-NTAXA, PSI)	Freshwater macrophyte index
Freshwater habitat condition indices for sediments* and nutrients*	Freshwater C*oleoptera, Odonata* and *Megaloptera* richness
Greenhouse gas emissions*	Freshwater uncommon macrophyte index

2.2 UKCEH land cover map for ecosystem extent and connectivity

ERAMMP used satellite data to estimate the National Trend of change in land use from 2010 to 2021 using an approach developed by UKCEH which has been producing land cover maps (LCMs) since 1990. These maps have been produced annually since 2017, with the 2022 and 2023 maps just recently published: (Marston, Morton, O'Neil, & Rowland, 2024); (Morton, Marston, O'Neil, & Rowland, 2024). This production of annual maps has been made possible due to advances in processing and satellite data by applying an automatically trained Random Forest classification algorithm to multi-temporal Sentinel-2 composite images (Carrasco, O'Neil, Morton, & Rowland, 2019) combined with a range of context layers. Context layers help the classifier to avoid spectral confusion between surfaces with similar spectra; for example, coastal sediment and urban sealed surfaces have similar reflectance properties but can be separated using coastal proximity.

Only recently has change in landcover been possible from these UKCEH LCM. Previously, methodologies were continually being improved meaning maps were not directly comparable. A consistent approach has now been developed allowing more recent maps to be compared with lower resolution satellite data enabling historic changes to be compared in five-year intervals for the UK albeit at lower resolution than the more recent LCM (Rowland, Marston, Morton, & O'Neil, 2020). This work is funded by UKCEH through its National Capability and is provided here as part of the UKCEH co-funding element of GMEP/ERAMMP.

Going forward, the WG has invested in the development of Living Wales (LW). As this is a new satellite derived product change, change data was only be available from 2018 onwards so could not be used for reporting on the trend over the last 10 years comparable to the NFS. A comparison of the UKCEH LCM and LW current habitat maps and the GMEP habitat mapping from the NFS has been carried out and has been reported in-depth (Maskell, et al., 2023). In brief, the methodologies, purpose and classes of the approaches all differ, making comparison somewhat challenging. This is particularly true in upland areas where there is significant variation in habitat as many occur in mosaics with many areas a complex mix of transition zones. Assigning continuously varying surfaces into discrete categories can be difficult, especially for borderline cases. To overcome difficulties like this, field surveyors make judgements based on the presence or absence of indicator species but it is not possible to detect indicator species from space. Satellite-based habitat decisions are based purely on energy spectra and context. Spectra are determined by dominant cover with a specific pixel size (which has become smaller over time with higher resolution now possible). These interpretation differences almost certainly have significant effects when comparing field- and satellite-based information. It should be noted that neither approach is the 'truth'. Both have strengths and weaknesses.

Change in land cover / broad habitats for the period 2010-2021 for all categories are shown in Table 2-3 3. A total of 6.8% of Wales changed allocation to a land use / habitat class in some way. Note some smaller changes are likely to be within detection limits. Semi-natural land including Broadleaved Woodland represented 43% of Wales in 2021.

Table 2-3 Change in land use/habitat area (ha) as estimated by UKCEH LCM between 2010 and 2021 including the combined estimate of Semi-Natural Habitat with and without Broadleaf Woodland. The former is WFG National Indicator 43. The latter helps to identify change in non-woodland areas.

Land Use / Habitat Class	2010 (ha)	2021 (ha)	Change 2010 to 2021 (ha)
Arable	110,000	84,100	-25,900
Improved Grassland	876,300	853,300	-23,000
Acid Grassland	457,800	449,600	-8,200
Neutral Grassland	43,600	46,800	+3,200
Calcareous Grassland	2,000	400	-1,600
Broadleaved Woodland	186,800	216,000	+29,200
Coniferous Woodland	148,000	142,400	-5,600
Dwarf Shrub Heath	86,000	88,200	+2,200
Fen, Marsh, Swamp	14,200	12,600	-1,600
Bog	15,900	20,400	+4,500
Inland Rock	10,500	4,600	-5,900
Freshwater	9,500	10,000	+500
Coastal	62,000	66,000	+4,000
Built-up	98,500	126,700	+28,200
Total	**2,121,100**	**2,121,100**	**Sum of +/- area = 143.6 (6.8% of Wales)**
Semi-Natural Habitat* with Broadleaf Woodland (WFG #43)	**878,800**	**904,600**	**25,800 (+1.2% of Wales)**
Semi-Natural Habitat* without Broadleaf Woodland	**692,00**	**688,600**	**-3,400 (-0.2% of Wales)**

**All land excluding Arable, Improved Grassland, Coniferous Woodland, Freshwater and Built-up.*

For the purposes of the new proposed SLM ecosystem health and resilience indicator, extent of 10 semi-natural habitats only are included i.e. excluding Arable, Improved Grassland, Coniferous Woodland and Built-up extent change. This provides a focus on habitats prioritised by the current WFG indicator.

From the NFS, an additional 2 extents can be added, that of the estimate of national hedge extent and number of individual trees (defined as a single tree being 50m distance from another tree) Table 2-4).

Table 2-4 Indicators of diversity and connectivity for all of Wales estimated from the UKCEH land cover map for 2010 and 2021 and their direction of change. See ERAMMP Report-105 for methods.

Indicator	2010	2021	Change (+, - or =)
National estimate of Hedge length (1000s of km)	50.5	52.7	+
Number of individual trees (mean per square)	28.14	26.74	=

The UKCEH LCM has also been used to estimate one additional diversity indicator, that of overall habitat diversity across all of Wales, and four connectivity indices for woodlands, wetlands, grasslands and heathlands (Table 2-5).

Table 2-5 Indicators of diversity and connectivity for all of Wales estimated from the UKCEH land cover map for 2010 and 2021 and their direction of change. See ERAMMP Report-105 for methods.

Indicator	2010	2021	Change (+, - or =)
Diversity			
Habitat diversity	0.82	0.74	-
Connectivity			
Broadleaved Woodland	0.9	0.9	=
Wetland	0.98	0.98	=
Grassland	0.85	0.88	+
Heathland	0.97	0.97	=

To review trend data for individual broad habitats and landscape features, see ERAMMP Report-105 where this is described in detail across multiple chapters. Here we focus on bringing together the data to create a single ecosystem indicator potentially useful for high level national scale reporting.

3 CREATING AN INTEGRATED ECOSYSTEM INDICATOR

A total of 268 measurements and indices are available from the combined data resources of the ERAMMP NFS and the UKCEH LCM described in Section 2.

These have been assigned to four of the five DECCA categories together with their direction of change (i.e. improved, no change or decline) from 2010-2013 to 2021-23 (Table 3-1).

Table 3-1 Counts of measurements and indices assigned to four categories which contribute to ecosystem health resilience and the overall split as a percentage of all counts.

DECCA category	Improved	No change	Declined
Diversity	2	59	16 (21%)
Extent	7	1	4 (33%)
Condition	11	124	40 (23%)
Connectivity	1	3	0 (0%)
All combined	21 (8%)	187 (70%)	60 (22%)

Using these direct counts could be used to define a target being to either 'hold the line' and not increase indicators of decline still further, or reduce the % of total indicators in decline from 22% to perhaps 17% over 5 years.

However it may be preferable to weight them so of the 5 resources, broad habitats and landscape feature and each DECCA category contributes equally to the overall assessment (Table 3-2). This results in a shift in balance between improved and no change categories but the decline category remains stable at 22%.

Table 3-2 A comparison of change ecosystem data using either direct counts or weighted by DECCA category.

% of indicators	Improved	No change	Declined
Counts	8%	70%	22%
Weighted by DECCA category	23%	55%	22%

Irrespective of the selection as to whether to use a simple, unweighted count of indicators (as for the species indicator), or to weight the counts according to resource, habitats and DECCA category, the use of the new indicator to track SLM impacts seems to be an approach which exploits the major investment by WG in capturing high quality, nationally representative field data from the ERAMMP NFS and the only current legacy EO data which can be used to track habitat extent change over the last 10 years. Perhaps most notably it significantly moves us on from the current WFG Ecosystem Area indicator 43 which captures only change in extent of semi-natural habitats.

4 Comparing State of Nature 2024 All Species Trends with Ecosystem diversity data and the Integrated Ecosystem indicator

A comparison of data relating to species decline from the State of Nature 2024 report for the period 2010 to 2020, the NFS ecosystem diversity data only and all of the NFS ecosystem data for 2010-2023 is shown in Table 4-1. The results suggest:

a) Diversity data captured by the ERAMMP NFS has lower levels of decline relative to the State of Nature report for abundance of individual species report. This could be due to the greater sensitivity of species to drivers of change included in the State of Nature report compared to ERAMMP NFS which only covers vegetation, birds, pollinators and diversity in small water bodies. Another explanation is the type of land cover by the two programmes with State of Nature biased towards conservation and designated land relative to the more nationally representative structured approach of the NFS.
b) Metrics for ecosystem health and resilience provide different insights over and above that of diversity alone with diversity perhaps showing greater sensitivity to drivers of change relative to condition, extent and connectivity.

Table 4-1 A comparison of the recent trends for all species abundance (2010-2020) and ecosystem diversity count data only, and all ecosystem DECCA data using either direct counts or weighted by DECCA category (2010-2023) presented in this report.

% of species diversity metrics	Improved	No change	Declined
All Species Abundance (State of Nature 2024)	32%	25%	43%
Integrated Ecosystem Health and resilience indicator (Diversity count data only)	3%	77%	21%
% of ecosystem metrics			
Integrated Ecosystem health and Resilience Indicator (Counts)	8%	70%	22%
Integrated Ecosystem health and Resilience Indicator (Weighted by DECCA category)	23%	55%	22%

5 DRAFT RECOMMENDATIONS

A. To exploit WG investment in capturing nationally representative data from the ERAMMP NFS and UKCEH's investment in the land cover map to support the development of a new 'Ecosystem Health and Resilience' indicator.

B. To use 57 individual measurements which have been assigned to 4 of the 5 DECCA categories to track change for 19 broad habitats and landscape features (a total of 268 measurements and indices) for the creation of this new integrated indicator.

C. To set a target relating to the % of measurements and indices which are in decline from the current value of 22% in decline over the last 10 years using a weighted approach balancing the contribution of the 4 DECCA categories. That target to be set by Welsh Government as it will be linked to resources available through SLM to achieve any set target.

D. For this indicator to be refined and improved over time as new data sources and approaches become available and the methodology refined.

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