Botanical data processing: Methods used to collect and analyse data on floodplain meadow restoration sites.

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Five botanical quadrats (1 x 1 $m^{2)}$ are surveyed in each restoration field, randomly distributed across the site. Species abundance is assessed in each quadrat as percentage cover.

Data analyses methods include:

1. Calculation of species richness per quadrat (number of species per $1m^2$) and averaged across 5 quadrats.
2. Analysis of quadrat data using the MAVIS calculator (Centre for Ecology and Hydrology), which generates three major characteristics of the vegetation:
    2a. Similarity to National Vegetation Classification (NVC) reference plant communities (Rodwell, 1992).

    2b. Plant indicators of soil condition (Ellenberg).

    2c. Functional diversity of vegetation (Grime).

3. Comparison of figures to national dataset of floodplain meadow restoration sites.
4. Assessment of vegetation to see if it meets criteria for inclusion in the Priority Habitat Inventory for Lowland Meadows.

Methods of analysis for 2 and 3 are described in a little more detail below:

2a. National Vegetation Classification (NVC)

Among vegetation described as mesotrophic grasslands, two types of permanent grasslands have been of particular interest for conservationists: MG4 (*Alopecurus pratensis – Sanguisorba officinalis*) and MG8 (*Cynosurus cristatus - Caltha palustris*). These two types are among the most species rich types of mesotrophic grasslands in the British Isles and are found on floodplains. Subcommunities of MG4 and MG8 grasslands have been identified, reflecting the dynamic nature of vegetation along hydrological gradients (Wallace and Prosser, 2016). The MAVIS calculator provides the ten top similarity scores to the published communties at the subcommunity level. We assume that the top two plant communities/subcommunities reflect a level of similarity between the restoration site and the NVC reference communities. A similarity score of over 60% is considered as an indicator of very good progress/success of the restoration site towards one or another types of mesotrophic meadow.

2b. Ellenberg indicators of soil condition

MAVIS calculates 'Ellenberg' scores for soil condition in the surveyed sites, using information about known plant tolerances to soil fertility, soil moisture and other environmental variables as a proxy (Ellenberg, 1988). The approach is widely used in the interpretation of botanical data. Ellenberg scores measure soil reaction (R), soil fertility (N) and soil moisture (F).

A site with Ellenberg values that indicate a high soil fertility or high soil moisture tolerance in the plants will suggest particular management recommendations if the objective is for a species rich floodplain meadow.

A high level of nutrients in the soil supports fast growth of highly competitive species, mainly grasses. They outcompete herbs and reduce species richness of the meadow. Flood sediments, which are very nutrient rich, shift the soil nutrient balance towards higher values. An effective way of reducing nutrient content in the soil is a hay cut. Timely hay cuts (mid-June) remove large amounts of nutrients absorbed by plants by that time of their seasonal growth. By the middle of July, most nutrients return below ground and are deposited in perennial parts of plants as their roots and rhizomes, meaning nutrients return to the soil. On sites with high nutrient content in the soil, a double hay cut, at the beginning and at the end of summer, is highly recommended. We use Ellenberg indicator values to support our recommendations on site management, in terms of soil nutrients and soil moisture, in particular.

2c. Grime – Functional diversity of vegetation

One further type of data analysis provided by MAVIS is the calculation of the functional diversity of vegetation. This approach was developed by Grime (1974) and his successors (Hunt et al., 2004) for evaluation of species strategies in interaction with other species in a plant community. With regard to meadows, it was shown that good functional diversity as a balance between the number and abundance of competitive species (Grime's category C), stress-tolerant species (category S) and ruderals (category R) is difficult to achieve in meadow restoration (England & Wilkes, 2018; Jones et al., 2019). The sites where this functional diversity is well-balanced can be considered to have very good restoration success, getting close to the conservation target of species-rich semi-natural ancient floodplain meadows (e.g., MG4 type). This balance can be measured as a ratio between (a) competitors and stress-tolerant species and (b) stress-tolerant and ruderal species. If all three functional groups are equally presented in the community, its functional diversity is regarded as very good. In that situation, C:S and S:R ratios are close to "1". Where values are more or less than 1, then the functional diversity is considered to be less well balanced, and management recommendations will follow that hope to re-dress the balance.

3. Comparison of figures to national dataset of floodplain meadow restoration sites

During a national survey of meadow restoration projects (2016-2018), we developed a scale which allowed an assessment of progress in restoration of meadow vegetation on the restoration fields visited (Rothero, Tatarenko & Gowing, 2020). An example of such a table is shown below. It gives a reference range of numbers for four main "success criteria" of

meadow restoration: species richness, NVC similarity score, and C:S and S:R ratios. All reference values have been obtained from real data collected on 165 restorations sites across the UK, as well as from botanical surveys of ancient British floodplain meadows.

	Progress (1 = poor progress, 5 = excellent progress)				
Measure	1	2	3	4	5
Average scores from five botanical quadrats per field. Calculated in MAVIS					
Species richness (number of species per 1 m^2)	<8	8 to 12	13-15	16-20	>20
NVC similarity score	<50%	50-55%	55-60%	>60%	>60%
C:S ratio	1.65	1.39	1.23	1.1	1.09
S:R ratio	0.67	0.79	0.81	0.89	0.93

Table 1. Five categories of meadow restoration progress, measured by indicator scales based on species richness, NVC similarity score and ratios of Grime's plant functional types. Adapted from Rothero, Tatarenko & Gowing, 2020.

Results of the data analysis from a particular site can be allocated to the cells in the reference Table 1 (as highlighted in yellow in the table). This immediately shows how well restoration is progressing on the site and which aspects should be addressed.

Low values for 'species richness' usually suggest further application of species propagules (seeds/plug plants) are desirable on the site.

Low values of NVC similarity scores imply that species are not evenly distributed across the site yet, and they haven't formed a recognisable NVC community.

High values of C:S and low values of S:R mean that the site is either heavily dominated by competitors (C:S>1.39) or ruderals (S:R<0.78). In those cases, change/modification of management is required, e.g. early and/or double hay cut.

The scales shown in Table 1. are very sensitive, with given steps between the "progress categories" as small as 0.1-0.3 points in functional diversity criteria, and 3-5 species in species richness criteria. Because of this sensitivity, the scales can reflect annual dynamics on sites caused by extreme climate events like droughts or floods. However, we still believe the scales are an effective tool for measuring overall progress in meadow restoration projects.

5. Priority Habitat Inventory

Natural England's Priority Habitats' Inventory (PHI) is a spatial dataset available here https://www.data.gov.uk/dataset/4b6ddab7-6c0f-4407-946e-d6499f19fcde/priority-habitats-inventory-england that describes the geographic location and extent of 25 priority habitats in England. It maps most of the terrestrial semi-natural habitat types that were

identified as being the most threatened and requiring conservation action under the UK Biodiversity Action Plan (UK BAP). One of these habitats is Lowland Meadows, and floodplain meadows fall within this habitat type.

For sites to qualify as PHI sites, a survey must show that they contain a range of particular indicator species, listed according to the habitat in question. If sufficient of these species are present in sufficient amounts, then the site can be considered to comply. To become registered on the PHI, the survey must be submitted to Natural England for checking, and if accepted, will be added on to the mapped dataset, available through MAGIC https://magic.defra.gov.uk/magicmap.aspx

Inclusion on the PHI often means landowners are more likely to receive agri-environment scheme funding. We have used the PHI criteria for Lowland Meadows (floodplain meadows specifically) to check if the sites we visit qualify for the PHI. We have written our findings into the report, and if the site qualifies, we recommend that it is submitted to Natural England.

References

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