STANDARD CRITERIA & METHODS TO ASSESS THE RECLAMATION OF NATIVE VEGETATION ON MINED LAND[1]

by

R N Humphries [2] and P R Benyon [2]

Abstract There is currently much interest in the re-establishment of native (semi-natural) vegetation in mineral workings in the UK. It is expected that future planning consents will have conditions attached which require evidence that the proposed communities have been achieved. At present there is no standard approach. This paper describes a formal sample based method which enables assessment of plant community, species richness and species of particular interest at any point in time and their course of development. The method is illustrated by use of data collected for sown grassland on a restored opencast coal site in South Wales. Further development work is likely to be necessary and comparison with other recently recommended methods is suggested.

Additional Key Words: vegetation monitoring, plant communities, species richness, species interest, mined land assessment.

Introduction

It has long been appreciated that mineral workings can be important for wildlife. Much of the wildlife value of workings in the past has developed through natural colonisation following abandonment over a number of years. There has until relatively recently been little interest in the re-establishment of native (semi-natural) vegetation in the UK.

The interest in the restoration of native vegetation after working land for minerals in the UK has been fuelled by the government's recent biodiversity policies and initiatives (UK Government, 1990 and 1994). Mineral workings are now seen as potential major contributors to the UK species and habitat initiatives (English Nature, Quarry Products Association and Silica & Moulding Sands Association, 1999). As a result it is expected that there will be a large number of applications for planning permission which will propose the restoration of native vegetation, especially if the workings would in the first place mean the disturbance of existing areas.

It is expected that future planning consents will have conditions attached which require evidence to be collected that the proposed vegetation has been established. Either there could be a requirement to establish a natural type of vegetation community to replace one which existed before mining or introduce one which was appropriate or desirable. Alternatively, there could be a requirement to introduce a synthetic community comprised of native species. In all cases it would be expected that the specified sown or planted species would establish, and this needs to be measured and assessed. At present there is no standard approach, methods or criteria, whereby objective assessments can be made in the UK. Without standardisation it will not be possible to arrive at consistent assessments. A similar need for standard procedures has been called for in the USA by Vincent (1998). He noted the limitations of similarity indices suggested by Tierney and Wade (1998) and others, and the general lack of consensus about the appropriate methods for mined land. He also suggested a simple yet pragmatic interim method for general use.

The purpose of this paper is to suggest a formal approach based upon experience of monitoring of native vegetation re-establishment at several mine sites in the UK.

[1]Paper presented at the 16th National Meeting of the American Society for Surface Mining and Reclamation, Scottsdale, Arizona, August 13 - 19, 1999.

[2]Consultants, Humphries Rowell Associates, Loughborough, LE11 3NP, UK.

Proceedings America Society of Mining and Reclamation, 1999 pp 72-80
DOI: 10.21000/JASMR99010072

https://doi.org/10.21000/JASMR99010072

Rationale

There are three key components of vegetation that require attention. These are community type, species richness and species of particular conservation importance. Other categories could be added if required (eg. those species having an erosion control function).

Community type is usually defined by a small number of species with high frequencies of occurrence. An example of a simple community is *Agrostis stolonifera - Alopecurus geniculatus* inundation grassland. It is characterised by the constancy of just these two grasses in samples, even though typically up to seventeen species are associated with the community type. Other communities may be characterised by more species, but all would be of constant occurrence. This approach forms the basis for the current National Vegetation Classification (NVC) system in the UK (Rodwell, 1991 & 1992).

The other species occur less frequently and hence do not contribute to the character of the community. However, they may contribute to the quality of the community in terms of species richness and species of conservation interest, as well as its ability to function. The determination of community type (constant species), species richness and species of conservation interest provides a means whereby the achievement of the required vegetation can be assessed.

The basic requirement for this kind of assessment is the recording of species and a measure of their frequency in replicate quadrats. There are several ways in which this can be undertaken (Greig-Smith, 1964). However, standardisation will be required if the data are to be meaningful and to be applied more widely.

The achievement of plant community type, whether it be a successional precursor or the climax form, can be determined simply by comparing that recorded with a standard, be it a natural or synthetic type. Computer programmes are available for comparing the similarity of a sampled vegetation to the published UK National Vegetation Classification type (NVC) (Malloch, 1990; Hill, 1991). There are also standard techniques whereby community composition of sampled vegetation from different areas can be compared or samples from the same vegetation and its development tracked over time by repeated sampling (Hill, 1979). This approach can use species presence, cover or frequency data.

The achievement of species richness can be determined simply by setting appropriate limits, and levels for species of interest in terms of their occurrence and abundance. The progress of these can also be tracked as time sequences.

An Example

The objective of the following example was to establish native grassland of nature conservation interest.

Approximately 3.5ha of newly restored land at the Gilfach Iago opencast coal site in South Wales was sown in late summer1993 with seed collected mechanically from nearby native grassland (Bell and Humphries, 1992). The communities harvested were i) *Cynosurus cristatus - Centaurea nigra* hay meadows (AF), ii) *Cynosurus cristatus - Centaurea nigra / Juncus effusus - Juncus acutiflorus - Galium palustre* meadow - wet pasture gradation (GH), iii) *Molinia caerulea - Potentilla erecta* mire (BC1) and iv) *Molinia caerulea - Cirsium dissectum* fen meadow (BC2) with sedge lawns of carnation sedge (*Carex panicea*) and oval sedge (*C. ovalis*). Within the restored area, three (B, D and E) were sown with seed from grasslands AF, GH and BC (1 & 2 combined) respectively (Humphries and Benyon, 1994).

The donor grasslands were monitored in 1992. The cover abundance of species occurring in 5 or 10 replicate 2m x2m quadrats was recorded within typical parts of the fields. The sown areas have been monitored annually since 1994 recording species and rooted frequency in 20-30 replicate 0.5m x 0.5m quadrats.

Achievement After Five Years

Plant Community Type

The community constant species are those which occur in 60% or more of the samples (Constancy Classes IV and V sensu Rodwell, 1991). The constants in the source and the sown grassland are given in Tables 1 and 2 respectively (the full list of species and constancy classes have been omitted for clarity).

Table 1. Summary Community Table of Constant Species* in Seed Source Fields in 1992

Seed Source	AF	GH	BC 1	BC 2
Anthoxanthum odoratum	V	V	V	
Cynosorus cristatus	V	V		
Trifolium repens	V	V		
Holcus lanatus	V	IV		
Ranunculus repens	V			
Rhinanthus minor	V			
Plantago lanceolata	IV			
Ranunculus acris	IV			
Carum verticillatum		V	IV	IV
Carex ovalis		V		IV
Lotus corniculatus		V		
Festuca ovina		V		
Nardus stricta		IV	IV	V
Carex panicea		IV		V
Juncus acutiflorus		IV		
Agrostis capillaris			V	V
Molinia caerulea			V	V
Potentilla erecta			V	V
Luzula multiflora			IV	
Danthonia decumbens				V
Carex echinata				IV
Carex nigra				IV

* constant species (classes IV / V) with > 60 % frequency

Table 2. Constant Species* in Sown Areas in 1998

Area Sown	B	D	E
Seed Source	**AF**	**GH**	**BC 1 & 2**
Agrostis capillaris	V	V	
Trifolium pratense	V		
Plantago lanceolata	V	IV	
Holcus lanatus	IV	V	V
Anthoxanthum odoratum	IV	IV	
Cynosurus cristatus	IV	V	IV
Ranunculus repens		V	
Juncus effusus			IV
Carex ovalis			IV

* constant species (classes IV / V) with > 60 % frequency

The eight constant species of the AF source were characteristic of dry mesotrophic (neutral) grassland (Rodwell, 1992). In contrast, the 7 and 8 constant species in the BC sources were characteristic of wet and acidic poor fen and mire communities (Rodwell, 1991). The 11 constants of the GH source were a mixture of those from the AF and BC sources, and indicating an intermediate community.

In 1998 area B had 6 of the 8 constants indicating a dry mesotrophic grassland had established. In contrast, 4 constants were recorded in E with only one in common with the constants of the source, suggesting that a different community had established. The six constants in D were the dry mesotrophic types associated with the GH source, indicating that a drier more mesotrophic type of grassland had established.

Species Richness

Species richness is defined as the mean total number of species per unit area and are given for each of the source and sown grasslands in Tables 3 and 4 respectively.

Table 3. Species Richness of Seed Source Grasslands

Seed Source	Quadrat Size (m)	Mean Number of Species/Quadrat
AF	2 x 2	18.2
GH	2 x 2	15.8
BC 1	2 x 2	9.3
BC2	2 x 2	10.0
AF type (*)	0.5 x 0.5	13.5
BC type (*)	0.5 x 0.5	14.4

* nearby grassland

Table 4. Species Richness of Sown Grassland in 1998

Area Sown	Quadrat Size (m)	Mean Number of Species/Quadrat
B	0.5 x 0.5	8.8
D	0.5 x 0.5	8.1
E	0.5 x 0.5	9.1

Unfortunately different quadrat sizes were used (because the harvesting and sowing trials had been undertaken as independent studies) at the seed source assessment stages and the post establishment monitoring, hence direct comparisons between the data needs caution. Data from the same sized quadrats from similar grasslands nearby suggest that the species richness estimates for the BC source may also be representative of smaller quadrats. The estimate for the AF may be higher than smaller quadrats.

In terms of species richness, a similar level appears to have established by 1998 in E, but not in grassland B and D.

Species of Conservation Interest

Plant species of particular conservation interest in grasslands and related vegetation in the coalfields of Britain have been identified from the site descriptions for statutory protected sites of wildlife importance (Sites of Special Scientific Interest) (Horton, 1991). Such species are usually particularly uncommon or endangered. One such species occurring in all three source grasslands was the whorled caraway (*Carum verticillatum*).

The frequency of occurrence of whorled caraway varied between the grassland types with the highest in the GH type, where it consistently occurred as a constant, and the lowest in the mesotrophic AF type (Table 5). It also occurred at a high frequency in the BC grasslands. In 1998 it was present at very low frequencies in area E sown with seed from BC. It occurred at low frequency in B sown with AF and a moderate frequency in D sown with GH (Table 6).

Table 5. Abundance of Whorled Caraway in Seed Source Grassland

Seed Source	Frequency of Abundance of Whorled Caraway (%)
AF	1 - 20
GH	81 - 100
BC 1 & 2	61 - 80

Table 6. Abundance of Whorled Caraway in Sown Grassland in 1998

Area Sown	Frequency of Abundance of Whorled Caraway (%)
B	6
D	25
E	0 *

* present outside of quadrats

Trends Over The Past Five Years

Plant Community Development

Trends in community development of the sown grasslands can be examined using either the frequency data or the Constancy Classes (I - V) by indirect ordination techniques. Figure 1 illustrates the use of the detrended correspondence analysis programme DECORANA (Hill, 1979). The plot is for constancy data for all samples and species, but without weighting for frequency (ie in this example the less frequent species were given the same weighting as the constants). Relative to the two main axes (1 & 2) the source grasslands are well spread out, indicating a difference in species composition. The closer the points, the more similar the communities are in terms of species composition. Interestingly their relative position reflects the community constants referred to earlier, with the GH community being intermediate to the other types.

The BC source sown in area E is indicated in Figure 1 as developing, in terms of general species composition, towards its source over the five years, and possibly now has some affinity with the GH type. A similar but less pronounced trend appears to be occurring in D as it moves towards its GH source. In contrast, there is little trend in community B and it remains distinct in terms of overall species composition from its source AF.

It would be expected that the source grasslands would also show trends in community composition with time due to management and weather effects. Unfortunately, in this study the data was not collected, but should be a requisite of most studies if trends are to be examined.

Species richness

Trends in species richness can be simply examined, with or without statistical treatment. The three different areas displayed different trends. Area B had relatively high initial establishment by 1994 (Table 7), but this declined rapidly to the current level due to the 'closure' of the grassland in the absence of grazing. The species associated with BC were slower to establish, and hence area E remained open for longer with peak richness occurring between 1995 and 1997. This grassland is also beginning to close in the absence of grazing and there is evidence for a decline in richness. Area D displayed little overall trend.

Table 7. Species Richness of Sown Grassland Areas (1994 - 1998)

Area Sown	Mean Number of Species/Quadrat				
	1994	1995	1996	1997	1998
B	11.3	8.6	7.7	7.8	8.8
D	9.1	8.4	7.4	8.0	8.1
E	6.4	11.9	10.2	11.1	9.1

Species of conservation interest

Similarly trends in species of conservation importance can be examined. The whorled caraway has established in all three of the areas from the seed harvests (Table 8). The relative abundance appears to reflect that found in the three grassland types, with the highest in the GH sourced seed, area D, and least in the AF sown area B.

The irregular records in areas B and E reflect the low frequency and clumped nature of the species in these areas. The species has remained present in the grasslands since 1994 despite it not being recorded in some years. The species has become well established well in area D, and appears in all areas to be regenerating from seed.

Figure 1. Change in Sown Community Composition with Time

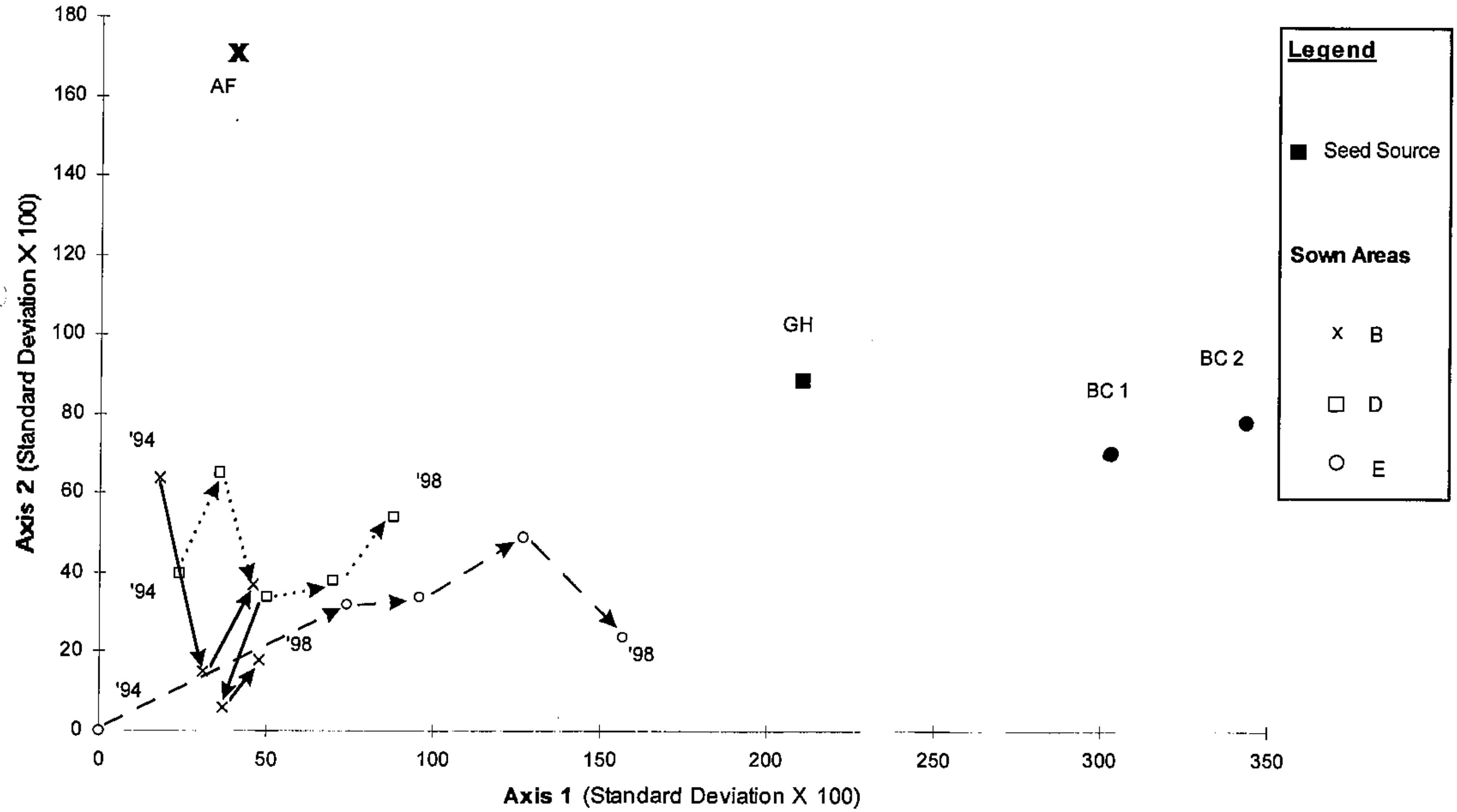

Table 8. Abundance of Whorled Caraway in Sown Grassland (1994 - 1998)

Mean Frequencies of Whorled Caraway/ Quadrat					
Area Sown	**1994**	**1995**	**1996**	**1997**	**1998**
B	0	3	0	0	6
D	9	6	9	31	25
E	0	10	5	35	0 *

* present outside quadrats

Assessment of Achievements

In terms of simple comparison with the source grassland the following could be concluded from the above.

The grassland in area B appears to be successfully developing as a similar plant community, in terms of its main (constant) species, to its source (AF). The apparent dissimilarity of the composition of the less frequent species suggests that the plant community could be subtly different. In contrast it appears to have failed in terms of re-establishing equivalent species richness, whereas it is probably achieving acceptable early levels of whorled caraway.

The grassland in area D appears to be developing a similar plant community, in terms of both major and minor species, to its source GH albeit slower than B. Again, species richness is lower than the source, whereas the sowing of whorled caraway has been very successful.

In contrast, the grassland in area E appears at present to be less like its source in terms of community type, however, there is evidence that development is taking place albeit slowly. This sowing seems to have achieved an equivalent species richness and probably satisfactory initial levels of the species of interest.

There are a number of explanations for some of the above and while such considerations are outside the purpose of this paper they are worth mentioning. Clearly the species actually harvested and sown is a material consideration as it is known certain species are easier to harvest than others (Bell and Humphries, 1992). This can affect both species abundance and species richness in the sown grassland. While this may explain the early low diversity and initial dissimilarity in composition, subsequent management can be a major factor and the lack of grazing is responsible for later changes or arrested community development.

Discussion

The approach described above for the Gilfach Iago site clearly enables the achievement of the target communities (intermediary or climax) to be determined and also their quality (species richness and species of interest) to be assessed. Besides meeting the basic requirements of vegetation composition and species richness cited by Vincent (1998), Tierney and Wade (1998) and others, the method described also provides data about individual species. This can be important where the interest is certain species, for example those of conservation interest, but could be for functional species too, such as those concerned with erosion control or successional processes. Lifeform and other information can also be derived from the same data base. The method, besides indicating the achievement of the targets, provides an indication of the direction and rate of development. This is essential information if decisions are to be made about the state of vegetation or its subsequent management. For example is it improving or deteriorating, or developing at all are as important questions as what has been attained. Inportantly, the described method provides the basis for a standard method as called for, and a data basis which is capable of interrogation in a number of meaningful ways.

Vincent (1998) quite rightly pointed out the practical constraints of collecting data in the mining situation and called for cost efficient methods; an essential ingredient if they are to be accepted and used. He favoured life form over species data because of its ease of collection and concern that sample based methods missed species without undue replication. However, it is difficult to see how objective data can be collected without collecting sample data, and its limitations should be accepted. There is the danger that if sample data are not collected it will not be possible to back track or rework data if simpler methods prove to be inadequate in the future, particularly if they are only interim. The incomplete listing of the scarcer species can be overcome by simply making an additional inventory list (with a quantitative assessment of abundance) as the formal recording is undertaken.

It is accepted that the sample based method described above is labour intensive, however it is robust in technical terms and is probably less open to various interpretations of method and practice than the less formal methods such as that described by Vincent. Our method is being effectively applied on a large scale in other schemes and has been accepted by the planning authority and regulatory bodies.

The basic requirements are as follows:

i) a formalised recording of frequency of species (eg appropriate number and size of quadrats), this would provide a standardised list of species present, species richness, and species of particular interest,

ii) the recording should take place at optimum time(s) annually (or an appropriate time sequence) until the required vegetation or a successional precursor has been established; the progress of this can be followed using the data by method described above,

iii) a standard is required against which judgement can be made (these may be the vegetation before mining or local example, or a published account); this should include a measure of the natural variation expected in the standard.

It is accepted that some further development of the approach may be necessary, and it would be interesting to apply the above approach in the USA alongside the methods described by Vincent (1998) and Tierney and Wade (1998).

References

Bell S and Humphries R N (1992) Harvesting seed from semi-natural grasslands in South Wales: A review of the 1992 programme. An unpublished report to British Coal by Humphries Rowell Associates, Loughborough.

English Nature, Quarry Products Association and Silica & Moulding Sands Association (1999) Biodiversity and Minerals: Extracting the benefits for wildlife. Entec, Newcastle upon Tyne.

Greig-Smith P (1964) Quantitative Plant Ecology. 2nd Edition. Butterworths, London.

Hill M O (1979) DECORANA: a Fortran program for detrended correspondence analysis and reciprocal averaging. Section of Ecology and Systematics. Cornel University, Ithaca.

Hill M O (1991) Tablefit. Institute of Ecology, Monks Wood.

Horton P J (1991) Chapter 2: Grasslands of nature conservation importance associated with the exposed coalfields. pp 7 - 44. In Transplanting Semi-natural Grasslands, Volume 1: Review and Guidelines. An unpublished report to British Coal by Humphries Rowell Associates, Loughborough.

Humphries R N and Benyon P R (1994) Gilfach Iago, 1994 report. An unpublished report to British Coal by Humphries Rowell Associates, Loughborough.

Malloch A J C (1990) Match: a computer programme to aid the assignment of vegetation data to the communities and sub-communities of the National Vegetation Classification system. Unit of Vegetation Science, University of Lancaster, Lancaster.

Rodwell J S (ed) (1991) British Plant Communities. Volume II, Mires and heaths. Cambridge University Press, Cambridge.

Rodwell J S (ed) (1992) British Plant Communities. Volume III, Grasslands and montane communities. Cambridge University Press, Cambridge.

Tierney R W and Wade G L (1998) Pre- and postmine diversity revisited. pp 564-571. In Proceedings of 15th Annual National Meeting of the American Society for Surface Mining and Reclamation, St Louis.

https://doi.org/10.21000/JASMR98010564

UK Government (1990) This Common Inheritance: Britain's Environmental Strategy. Commandment No. 1200. HMSO, London.

UK Government (1994) Biodiversity: The UK action plan. Commandment No.2428. HMSO, London.

Vincent R B (1998) Measurement of quantitative species diversity on reclaimed coal mine

lands: a brief overview of the Wyoming regulatory proposal. pp551-563. In Proceedings of 15th Annual National Meeting of the American Society for Surface Mining and Reclamation, St Louis.
https://doi.org/10.21000/JASMR98010551

Acknowledgements

We are grateful for the financial support from the British Coal Corporation and Celtic Energy, the successor coal company, the organisational assistance of Richard Pryce, Andrew Philips and Dylan Jones, and Dr Mike Gandy for his comment on the initial draft of this paper.