15 Grassland monitoring

15.1 Introduction

Grassland monitoring is part of the decision-making process required to manage semi-natural grasslands satisfactorily, as described in Chapter 3. The role of monitoring is to ensure that decisions made about management are correct, and if they are found to be incorrect, to help to identify how management should be adjusted.

The development of methods of grassland monitoring and their implementation received a great deal of attention in the 1980s and early 1990s in the UK, particularly in relation to the effects of management on the nature conservation value of semi-natural grasslands (Byrne 1991, Hodgson *et al* 1995, Critchley & Poulton 1994, Cameron *et al* 1997, Cummins *et al* 1997). Grasslands have been widely perceived as liable to rapid change in response to management. Consequently there has been a desire to ascertain that particular management practices are conserving semi-natural grasslands, and that the money spent on incentives to encourage management regimes favourable to these grasslands is actually producing positive benefits for conservation. This chapter outlines the most frequently used techniques and attempts to summarise best practice. There is no single method that is suitable in all circumstances. The choice of approach depends on the particular purpose of a monitoring project and the resources available to carry it out.

15.2 Definition of grassland monitoring

Grassland monitoring is here taken to mean any type of repeated recording of grassland vegetation or grassland management activities. The emphasis in the following sections is on outlining practical techniques and indicating ways that results can be interpreted. Details of the methods and approaches are contained in the references listed at the end of the chapter. The chapter does not cover direct monitoring methods for species of nature conservation importance although some of the approaches described, especially vegetation structure recording, could be adapted for indirect species monitoring. Standard direct methods are well described for birds (Bibby *et al* 1992) and butterflies (Pollard & Yates 1993). Monitoring of rare plant populations is discussed in Bradshaw (1981), Hutchings (1987) and Given (1994). Details of standard methods of monitoring environmental factors such as rainfall and soil hydrology are given in Sykes & Lane (1996). *The wet grassland guide* (Treweek *et al* 1997) includes an outline description and an example of hydrological monitoring.

Grassland monitoring can extend to the 'edges' of grassland where it adjoins other habitats. Such edges have not often been monitored but can be very important for conservation, for example tall-herb zones adjacent to scrub where NVC types such as MG2 (*Arrhenatherum elatius-Filipendula ulmaria* tall-herb grassland) occur. See Chapter 12 for a more detailed discussion of the nature conservation value of scrub/grassland edges.

15.3 Asking the right questions

It is of critical importance before starting any proposed monitoring project to clarify as precisely as possible the questions the project is expected to answer. Then the appropriate method can be chosen. This process of clarification is illustrated in Fig 15.1.

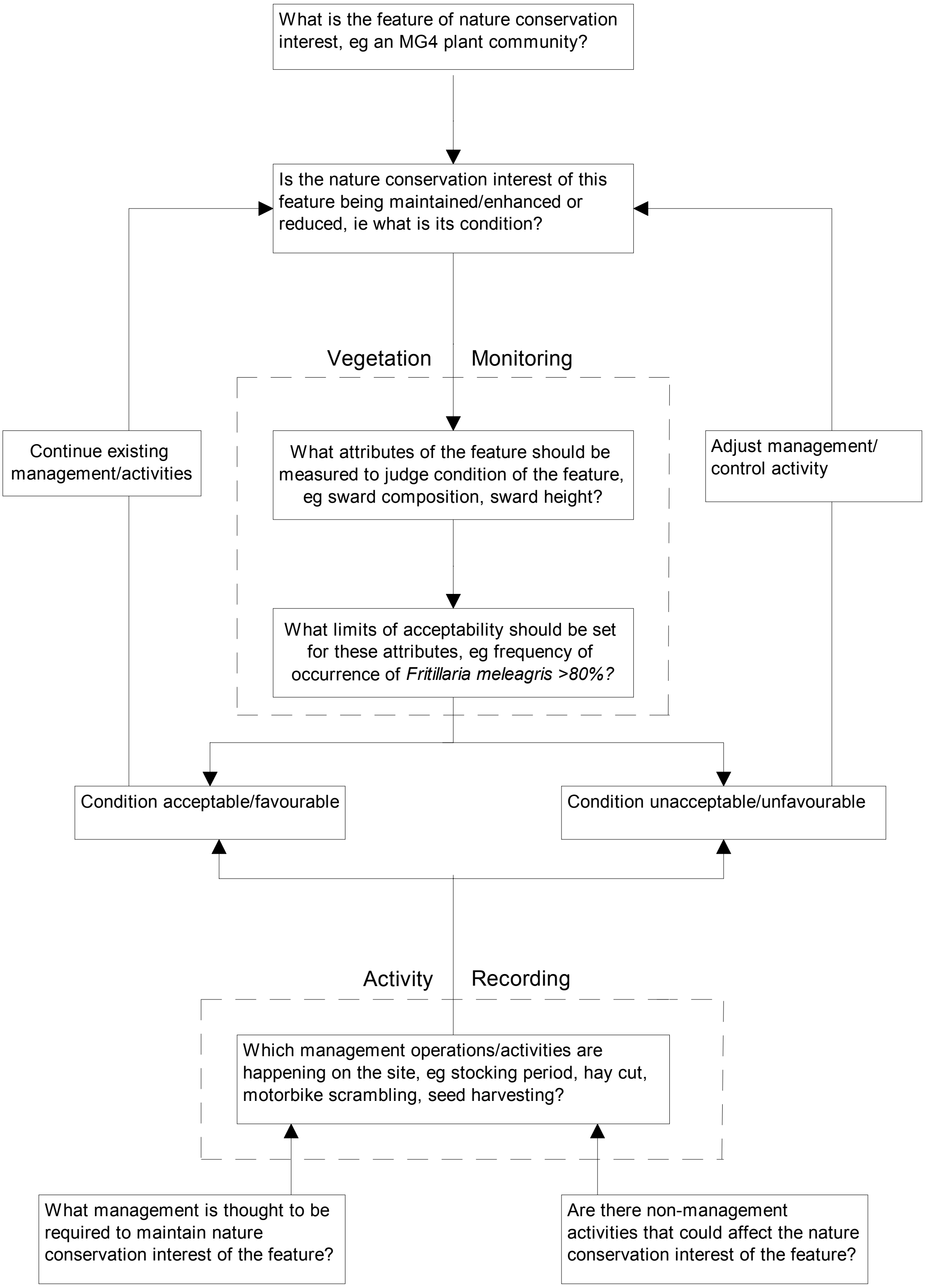

Figure 15.1 Questions to ask when considering a monitoring project

The structure and species composition of grasslands can vary quite considerably year to year particularly due to weather differences even if management remains stable. Plant populations, especially those composed of short-lived species can fluctuate quite widely, eg fairy flax (*Linum catharticum*) in chalk grasslands. Thus limits of acceptability for attributes of the nature conservation interest usually need to encompass a range rather than relate to one level only, eg a frequency between 5 per cent and 25 per cent, rather than, say, one of exactly 10 per cent.

If the vegetation only is monitored and no records are made of management operations or other activities, it can be difficult to decide how to adjust management or control other activities if the condition of the nature conservation feature is found to be unacceptable.

15.4 Vegetation monitoring: general issues

15.4.1 Resources and confidence

The resources available for vegetation monitoring are usually a major constraint on the choice of approach. Generally, the more detailed, time-consuming and costly the monitoring becomes, the more 'confidence' (statistical or otherwise) can be placed in the reliability of the results. Short-cut or 'quick and dirty' methods may be all that can be afforded but there should be validation of such methods against more detailed recording as well as clear understanding of their limitations by anyone trying to interpret the results obtained from them. Both rapid and detailed approaches are discussed in later sections of this chapter.

The importance of spending resources to get a reliable answer on a particular site might vary according to circumstance, for instance, a project to assess the effect of a novel management technique might receive more resources than one to check that traditional management that has been in operation for many years on a site is achieving the desired result. Detailed monitoring is usually costly in time and/or money so it is important to consider the rationale for such projects very carefully before embarking on them. Fig 15.2 illustrates the main choices available.

15.4.2 Frequency of monitoring

Decisions about frequency of monitoring are site specific and should relate to the nature conservation feature being recorded and the rapidity and scale of likely effects of management. There is no point having a monitoring interval that means that remedial action will come too late, eg monitoring a hay meadow after five years of farmyard manure input at rates thought originally to be on the heavy side, rather than monitoring after the first and second year. Resources will obviously play a part in deciding frequency of monitoring but careful definition of the questions to be answered and study of similar management situations can assist in deciding priorities for frequent monitoring.

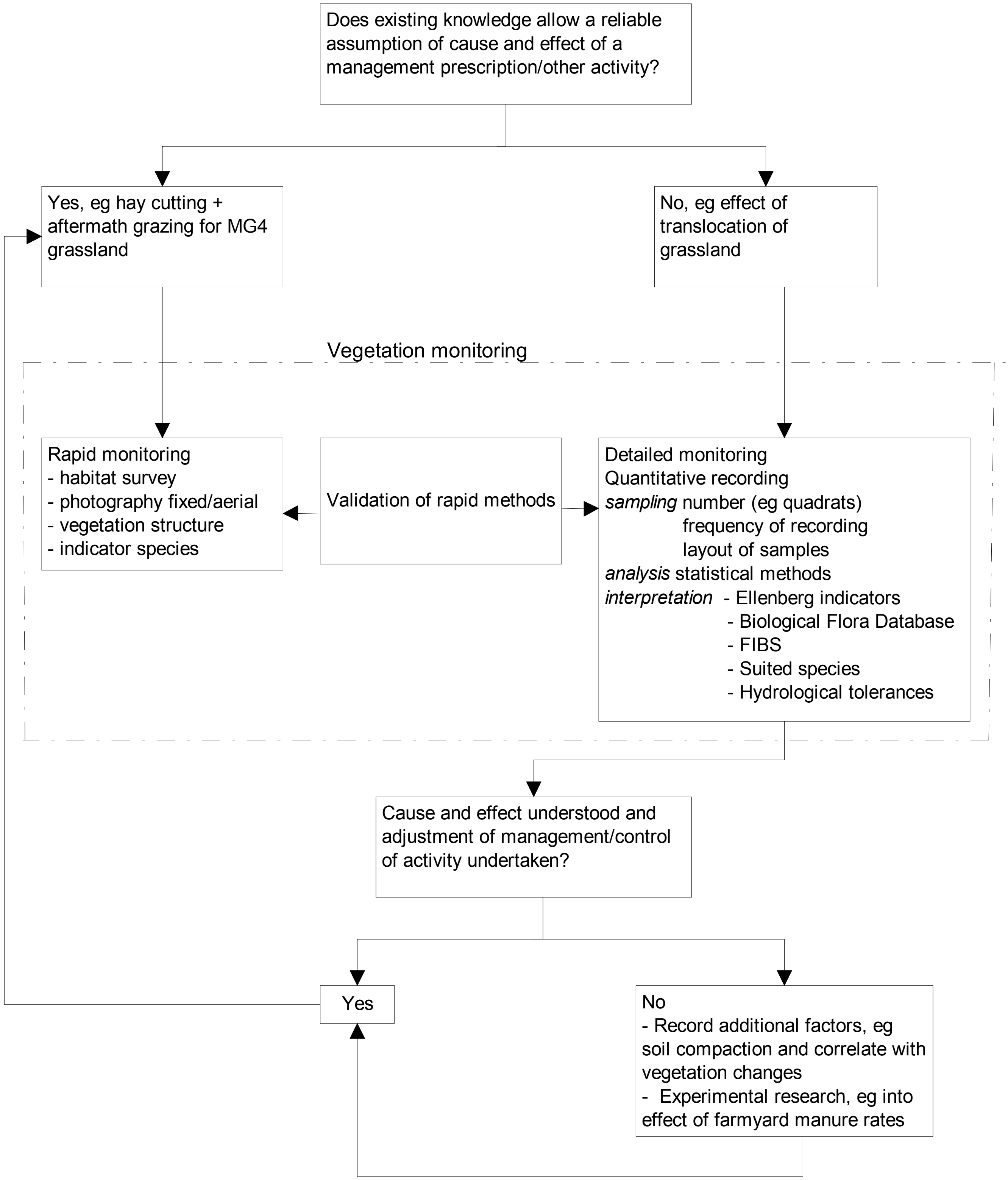

Figure 15.2 Choice of monitoring approach

15.4.3 Best practice

There are several general points to keep in mind when planning a monitoring project irrespective of the type of approach taken, although many of the following actions have particular relevance for detailed monitoring projects.

- Ensure the data collected can be readily analysed and interpreted. If carrying out a quantitative study, statistical analysis is usually required and certain sampling methods will need to be considered, particularly in relation to the distribution of samples on the site (random or otherwise). If the proposed layout or design of the monitoring programme is complex and if sophisticated numerical analysis is planned a statistician should be consulted before finalising the method. Bonham (1989) and Ross (1992) give introductions to possible statistical techniques for analysing monitoring data. A guide on data collection has been produced by Bell (1993) while Gibson and Brown (1992) describe an example of data analysis from a real long-term monitoring project.

- Determine as far as possible if the method chosen will detect real change of conservation significance, as opposed to 'noise' or 'random' variation. Where considerable resources are to be committed over several years it may be worth doing a small trial on the ground or with existing data, to assess the variability encountered. Again, consultation with a statistician can be of benefit. In quantitative studies, the number of samples required to detect change at a specified level is an important issue. For example if the project only detects statistically significant change when a difference over time, say of a species frequency, exceeds 80 per cent, this result is not likely to be helpful in fine-tuning management. Sample number is discussed more fully in Byrne (1991), Sokal and Rohlf (1995) and Krebs (1989).

- If change in the vegetation is expected after the introduction of a management activity, always try to obtain a baseline data set, before the activity occurs, so its actual effect can more clearly be discerned. Ideally the baseline would cover several years to enable variation due to weather to be identified. An alternative is to have a 'control area' nearby where the activity does not occur, which may be less satisfactory unless it is very similar to the area affected by the introduced activity.

- The sampling layout and recording methods should be described and archived properly so that repeat monitoring can be done consistently by different people from paper or computer records alone. For example a change in method from recording plants rooted in a quadrat to recording those with shoots in the quadrat may invalidate attempts to look at change over time across all years.

- Repeat recording visits should be carried out at the same time of year to reduce the effect of seasonal variability on the results. Ideally the vegetation should be recorded at the same stage of development each time as long as the criteria to assess this can be worked out.

- Sufficient resources must be allocated for statistical advice and analysis if a quantitative study is being undertaken, and for interpretation of the results and writing them up.

" The results should be analysed after every monitoring visit unless the project is intended to be very long-term. Even then, analysis intervals should be specified. For more immediate questions, the answer may be obvious after a few repeats, making further monitoring unnecessary. In addition, the frequency of monitoring or other aspects of the project may require revision in the light of early results.

15.5 Rapid methods of vegetation monitoring

15.5.1 Habitat survey

Mapping of grassland habitat types, ie Phase 1 survey (England Field Unit 1990) or Phase 2 survey (Smith *et al* 1985) of National Vegetation types (Rodwell 1991, 1992), will assist to a lesser or greater extent in the recognition of the continued existence of the grassland type for which the site is managed, or alternatively show that it has been lost. Generally such maps have been drawn by eye and are more accurately described as sketch maps. However, boundaries between vegetation types are often inexact on the ground anyway and such maps allow the recording of the approximate location and extent of vegetation types. Nevertheless, while a baseline map, say of NVC types, will enable changes in extent and in grassland type to be monitored, when taken in isolation it is usually rather a broad-brush approach where carried out for the purpose of adjusting management. It may only point to past change and may mean that remedial action comes too late. Where one or more quadrats or community species lists form part of the baseline and any repeat survey then these lists may be of use in the qualitative indicator species approaches discussed below. Knowledge of the distribution and extent of vegetation types is also useful in deciding the layout of more detailed monitoring samples across a site, for example, for deciding the priority areas to be monitored, or for distributing random samples among different 'strata' or homogeneous areas (stratified random sampling).

15.5.2 Photography

" **Fixed point photography**

Taking photographs from the same spot at different times can be a quick and effective way of monitoring changes that can be easily recognised visually. Examples are the spread of scrub or its retreat in the face of control measures, or the increase in bare ground because of trampling by people or livestock. Walker (1991) describes in detail how to take consistent and repeatable fixed point photographs.

" **Aerial photography**

Air-photos can readily provide 'historical' information, for example, about the spread of scrub, if photographs taken at different time periods exist, and they can be used to monitor such threats in the future, particularly over large areas of land. They can also assist with the mapping of vegetation types (see para 15.5.1), where these are readily recognisable from the air, and are especially useful for large, complex sites.

15.5.3 Vegetation structure

" **The importance of vegetation structure**

The physical structure of the grassland habitat significantly affects its suitability for plant and animal populations. Structure is usually taken to include vegetation height, presence of dead plant material or litter, and bare ground. Sometimes features such as tussocks and the cover or bulk of the sward are also described as part of grassland structure. Gaps in the vegetation provide regeneration niches for plant seedlings (Grubb 1976) and floristic changes in a grassland are often linked to changes in structure, for instance where a sward becomes tall and dense, regeneration of a species requiring short turf and gaps is prevented. Invertebrates require various structural features, for example the Adonis blue butterfly (*Lysandra bellargus*) selects for oviposition sites young horseshoe vetch (*Hippocrepis comosa*) plants which are adjacent to bare ground or which are growing over into small bare depressions in the ground (Butterflies Under Threat Team 1986). Other species use a mix of structural types, for example the wart-biter cricket (*Decticus verrucivorus*) needs short turf for larval development and taller tussocks where adults can hide and hunt (Cherrill and Brown 1990). Where mosaics of scrub and grassland are important eg for invertebrates, the size and density of scrub species are important components of vegetation structure.

Given the importance of vegetation structure, monitoring it can provide useful information for assessing the continued suitability of the grassland as a habitat for particular plant and animal populations and can provide clues about the likelihood of longer-term changes in these populations. Decisions about the 'ideal' structure to aim for through management, and against which to monitor actual structure, will depend on the conservation interest of the site. For example, for Breckland grass-heath (NVC types U1 and CG7), a sward height of 1-2cm may be appropriate for maintenance of lichens and annual plants, as well as suitable conditions for nesting stone curlew, whereas to maintain the floristic interest of species-rich chalk grassland (CG2) a sward of around 5cm might be satisfactory.

" **Recording vegetation structure**

The individual elements of vegetation structure can be assessed subjectively by eye or measured more objectively, for example by using sub-divided quadrats or a drop-disc. Definitions should be clarified before recording begins, for example is bare ground that which is visible when the undisturbed vegetation is viewed from above? This could be different to the amount of bare ground found when delving beneath the vegetation canopy. Litter is rather difficult to define as some senescent plant material is frequently present in grassland swards and may have little influence on habitat suitability. Usually litter is significant where it forms a distinct mat, often detached from living plant stems.

Quadrats: Sub-divided quadrats, say 1 metre square divided into 25 cells, can be used to work out the extent of vegetation cover, litter and bare ground. This can be expressed by frequency of occurrence in cells, eg 25 per cent of cells contain visible bare ground, or estimates of extent, eg five cells (25 per cent) have greater than 50 per cent extent of visible bare ground in each cell.

Drop-disc: A drop disc comprises a measured stick (eg a 1 metre rule) and disc with a central slot that fits over the rule. The height of the disc at rest after being dropped from the top of the rule is recorded. The measurement is of vegetation bulk, rather than height, but it has been used as an index of height because measurement of actual vegetation height is not easy. Component plant stems in a sward can vary greatly in height and it is often difficult to decide what is the general vegetation height. Discs have been made from wood, hardboard, metal or plastic and there appears to be no standard size or weight. The England Field Unit (Byrne 1991) and Butterflies Under Threat Team (1986) recommend a 30cm diameter hardboard disc weighing 200 grammes. Waring (1992) describes several sizes and weights and suggests that a 10cm diameter, 50gm disc may be more suitable for short swards on irregular ground. Summers and Critchley (1990) used a 275cm^2 polystyrene disc (approximately 18.5cm diameter) weighing 10gm. As no standard exists, it is most important to ensure that the same disc is used in any re-recording on a site. Large numbers of measurements can be made very rapidly, for example on North Meadow NNR the site manager could record 50 measurements at 5 metre intervals along a transect in 15 minutes (K. Payne, English Nature, pers. comm.). As well as the advantage of objectivity and simplicity, the measurements are repeatable by different people at different times. Results can be used to describe an average 'height index' or show the variation in sward height which may be of greater significance than average height.

A drop-disc has also been used to make rapid assessments of bare ground and litter on a presence/absence basis. When the disc is dropped, presence of bare ground or litter intersecting the edge of the disc is recorded (M. Wilkinson, English Nature, pers. comm.).

Sward sticks: Agriculturalists interested in herbage yield have used simple rulers to measure the surface height of the undisturbed sward, or a ruler with a perspex plate attached that is moved to make contact with the tallest leaf or stem encountered at the position of the ruler (Frame 1981, Rhodes 1981). There has been no comparison, as yet, of sward sticks and drop-discs for their relative value in recording structure for conservation purposes.

" **Timing the recording of structure**

When the measurements should be made will depend on the purpose of the monitoring. If the emphasis is on the immediate impact of management and its adjustment, for example aftermath grazing, recording structure during and at the end of the grazing period would be appropriate to check, for instance, on the change in extent of bare ground. If the suitability of grassland structure during the life cycle of a particular species is being assessed it would be more helpful to record during the critical part of this life cycle, eg during the spring period for annuals germinating in gaps at this time of year. Of course it is important to relate the results to the records made of management that occurred before this period.

15.5.4 Rapid assessment of plant species composition

" **Negative and positive indicator species**

The increase or decrease of particular plant species in a grassland can indicate more widespread changes in the habitat, eg the spread of ragwort *(Senecio jacobaea)* can be a symptom of overgrazed pasture. At the most general level, estimating the proportions of different groups of plants can indicate beneficial or deleterious changes. For instance the increase of grasses compared to broad-leaved herbs can relate to increases in nutrient availability, as in the change from species-rich neutral grassland (NVC type MG5 *Cynosurus cristatus-Centaurea nigra* grassland) to a species poor, grass dominated community (MG6 *Lolium perenne-Cynosurus cristatus* grassland) through the application of inorganic fertilisers. Similarly, neglect can allow coarse grasses like false oat-grass (*Arrhenantherum elatius*) and tor-grass (*Brachypodium pinnatum*) to spread at the expense of small herbs.

Choice of species to record is best made in relation to the particular nature conservation interest of the grassland eg northern hay meadow or calcareous grassland, but some general indicators can be suggested. In particular, negative indicators have quite wide applicability because inappropriate management of a wide variety of grasslands tends to move them all towards types akin to MG1 (*Arrhenatherum elatius* grassland) or MG6. Table 15.1 gives a list of possible negative indicators. Woody species could also be regarded as negative indicators where conservation of open grassland is the management objective. Other species might be appropriate in particular grassland types and locations, for example reed sweet-grass (*Glyceria maxima*) on the Ouse Washes, where it can replace more species-rich grassland and provide poor bird habitat (Burgess *et al* 1990). It is important to remember that "negative" indicators can be present in high quality swards in low amounts and thus it is the **amount** of a particular species that is of concern (see below).

Table 15.1 Potential negative indicators of grassland condition

Latin name	English Name
Anthriscus sylvestris	Cow parsley
Arrhenatherum elatius	False oat-grass
Brachypodium pinnatum	Tor-grass
Cirsium arvense	Creeping thistle
Cirsium vulgare	Spear thistle
Dactylis glomerata	Cock's-foot
Lolium perenne	Rye-grass
Phleum pratense	Timothy
Rumex crispus	Curled dock
Rumex obtusifolius	Broad-leaved dock
Senecio jacobaea	Ragwort
Trifolium repens	White clover
Urtica dioica	Common nettle

Positive indicators, showing maintenance of the nature conservation interest or its recovery are more specific to particular grassland types than negative indicators, for example squinancywort (*Asperula cynanchica*), stemless thistle (*Cirsium acaule*), rock-rose (*Helianthemum nummularium*) and salad burnet (*Sanguisorba minor*) might be among positive indicators for species-rich calcareous grassland.

" Recording indicator species

Ideally indicator species should have some predictive value, particularly so that remedial action can be taken before recovery becomes impossible. To get early warning it is usually necessary to know the abundance of the chosen species and any changes in their abundance. For example, knowing that rye-grass *Lolium perenne* is present is not much help, it could cover 100 per cent of the grassland, which would thus no longer have any conservation interest. Equally, swards of high nature conservation interest can contain small amounts of *Lolium*. Rapid subjective assessments of the abundance of particular species, can be made using the **D**ominant, **A**bundant, **F**requent, **O**ccasional, **R**are scale. These assessments may vary between observers (Leach 1991) and also among records made by the same observer at different times, so the significance of this variation needs to be assessed in terms of its effect on management decisions. For instance, if action would be taken when a negative indicator was at any abundance from Dominant to Frequent, any variation in assessment among these abundance categories is not important in the context of that decision. Using several indicators can increase the consistency of conclusions drawn from rapid assessments, although again different observers may record different lists from the same site. Precise quantitative recording is described in the next section but a half-way house to improve consistency in rapid recording is to use some kind of structured walk across the site. This might involve stopping at a defined number of points at which species are recorded and/or a timed search to try to achieve 'constant effort'. An example is given in Mitchley *et al* (1998).

15.5.5 Structured rapid assessments

The statutory nature conservation agencies in the UK are currently attempting to develop structured rapid assessment protocols for grassland SSSIs, using attributes such as sward structure and sward composition. This development follows on from the agencies' adoption of common standards for SSSI monitoring (Rowell 1993). Similar guidelines are being developed for re-created grassland (Mitchley *et al* 1998).

15.6 Detailed recording of botanical composition

15.6.1 Numbers of quadrats

Detailed recording of botanical composition is normally done using quadrats which demarcate small square, rectangular or circular areas of vegetation for intensive study. The importance of working out the number of quadrats to record (sample number) has already been referred to in sub-section 15.4.3. The number will need to be decided in relation to the required precision of the results and the variability in the monitoring area. For instance, if it is desired that a small change is detected, then a large number of quadrats will usually be required. It is very important to relate the decision about the size of change to be detected to the conservation significance of that change. As the sample number rises so does the (statistical) power of a test to detect (statistical) difference, say between species abundances at one time period compared with another. However these differences may not be significant in ecological or conservation terms. See sub-section 15.4.3 for references on sample number. Power of tests is discussed by Gerrodette (1987) and Green (1989).

15.6.2 Permanent versus temporary quadrats

Permanent quadrats have fixed positions which are relocated at each recording period while temporary quadrats are placed within the area of land to be monitored but removed after recording is done. A second set of temporary quadrats is placed at new locations in the same area of land at the next recording period.

The major advantage of permanent quadrats is that there is no variation in the data due to the effect of sampling, ie changes in values, say of species abundance, are real rather than due to the positioning of a new set of quadrats, as can happen when temporary quadrats are used. There can still be measurement error through, for example, the mis-identification of species.

There are a number of disadvantages attached to using permanent quadrats. Repeated recording concentrated in the same small area may itself cause changes in the vegetation, eg because of trampling or continued removal of material for identification. Setting up the quadrats so they can be found again, and the actual relocation are often very time consuming. Even if quite elaborate marking methods are used, permanent quadrats can be lost which is a serious drawback if only a relatively small number of quadrats were set up originally on a site. Changes in the quadrat over time are related - for instance, the appearance of a molehill will effect the vegetation recorded in the future, but such events may be localised and not representative of change in the area as a whole. Again this is a problem if only a small number of quadrats have been set up.

The locating of permanent quadrats needs to be done in relation to 'permanent' features in the area to be monitored, eg a boulder or fence post, to establish the general location of each quadrats. Distance measures and compass bearings are usually used, and this is done equally for locating large plots where temporary quadrats are to be recorded over time. The corners of each permanent quadrat should be permanently marked. Usually buried markers are required in grassland so that there is no interference by grazing animals or agricultural machinery. Byrne (1991) describes various methods of permanently marking and re-finding quadrats. New methods, as yet probably too expensive in most instances, are to employ very accurate Global Positioning Satellite (GPS) devices or surveying equipment using ground lasers. No permanent markers are required in these systems.

15.6.3 Layout of quadrats

“ **'Representative' quadrats**

The location of these is chosen subjectively and they cannot be combined for statistical analysis purposes because there is bias in the sample. For detailed monitoring they are not recommended as they require the same effort as other layouts described below, which are much more useful in producing results. However, recording one or two representative quadrats, eg as done in Phase 2 grassland survey can be helpful in rapid, subjective assessment methods, for instance, so the observer 'gets their eye in'.

“ **Random quadrats**

Random quadrats can be analysed statistically and a quantitative estimate of statistical 'confidence' in the results can be made. They are usually located on the ground by using random numbers, eg to pace out the coordinates of each quadrat in a larger plot or field. The random character means that each sample is independently located, which is important for statistical analysis. The layout can be completely random or random within pre-defined sub-areas (strata), eg the dry slopes of a field might be sampled as one stratum and the wet valley bottom as another. This subdivision can improve the coverage of variation within the site. It should be noted that different statistical methods are used to analyse these 'stratified random' samples compared to completely random samples (Scheaffer *et al* 1990, Watt 1997).

“ **Systematic quadrat location**

In this layout, quadrats are located at pre-determined intervals, either in a grid or along a transect. For example, in the monitoring method used by ADAS in the first Environmentally

Sensitive Areas (ESAs) in England and Wales, five quadrats are systematically located on a transect across a field (Critchley *et al* 1996). Grids are useful in detecting change in a site because samples are taken from all parts of the area. The grids used by the Environmental Change Network monitoring are described in Sykes and Lane (1996). Systematic samples are not placed independently of each other, in contrast to random quadrats, so strictly, statistical estimates do not apply. However, if there is a large number of replicates, systematic samples are often treated as random samples (Scheaffer *et al* 1990, Watt 1997). The main danger is bias in the samples, eg if a grid was laid out on a ridge and furrow field and only the ridge tops were sampled.

Sophisticated statistical approaches are being developed for the analysis of spatial data from systematic and random samples (Cressie 1993) that go beyond standard methods (eg Sokal and Rohlf 1995) but advice from a statistician is almost certainly necessary to implement these recent methods.

15.6.4 Improving precision in recording

The choice of detailed methods over rapid assessments implies that detailed methods are believed to give more precise results and that error in the results is not tolerated to the same extent. Much work on detailed methods has been done over the last 10 years, particularly by the England Field Unit of the Nature Conservancy Council (EFU), ADAS and the Unit of Comparative Plant Ecology (UCPE) in assessing sources of error and developing ways of reducing them. Sources of error are:

“ **Observer error in recording composition**

Grasslands present unique problems in consistent recording by the same or different observers. Grassland swards consist of a dense and complex arrangement of plants, some of which are challenging to identify, for example, small vegetative individuals of grass and sedge species. Even experienced observers have been shown to differ in their recording of the composition of the same quadrat, with a surprising lack of overlap. For example, Leach (1991) describes how 14 surveyors compiled separate lists for the same one metre square quadrat and the most accomplished surveyor only found 73 per cent of the total list. Only 36 per cent of the list was seen by all participants. Even the same observer re-recording the same quadrat can produce different lists (Poulton and Critchley, unpublished).

“ **Observer error in recording relative abundance**

In the past, most recording of relative abundance of individual species has been done by estimating subjectively the cover of each species in the quadrat, usually on the DOMIN scale of per cent cover (eg Critchley *et al* 1996). However, these estimates vary widely among observers and even for the same observer recording at different times (Poulton and Critchley, unpublished). Pairs of observers produce more consistent results (Hooper 1992) but mean that more expense is incurred. Recording cover more objectively using a pin-frame (described in Byrne 1991) has been regarded as excessively time-consuming.

Three recent monitoring methods

Recent development of approaches by the EFU, ADAS and UCPE has been aimed at overcoming the sources of error described above and thus producing more consistent data. The following descriptions of each method is only an outline and the references should be consulted for additional detail. The rough estimates of time taken for each method does not include the initial set-up time.

" **England Field Unit random mini quadrats**

The method was developed in the later 1980s, primarily to monitor a series of grassland transplants. Temporary quadrats of 10cm x 10cm size are located randomly in strips (strata) or completely randomly across the area to be monitored. Generally the EFU recorded around 100 mini quadrats per monitoring area. Experienced recorders were usually able to record between 50 and 100 quadrats in a full day. All vascular plant species, and sometimes bryophytes were recorded (Byrne 1991). The purpose of having a reasonable number of quadrats is that abundance of each species is to be objectively measured by its frequency, ie the total of its occurrences in the quadrats, such as presence in 80 out of 100 quadrats (80 per cent frequency). These frequencies can then be analysed to show relatively small changes in abundance. The aims of having a mini quadrat are that only a small area has to be searched, so improving the chances that different observers would record the same list of species, and that this list would accurately represent all the species present. A disadvantage is that while the commonest species appear in the mini quadrats when 50 to 100 of these are recorded, less common and arguably more interesting species often do not, making it difficult to draw conclusions about their changes in occurrence over time. Another drawback with regard to some species is the difficulty of identifying the very small pieces of vegetative plants found in such small quadrats. Larger quadrats usually have more definitive plant material. An example of the mini quadrat method in practice is given in Leach *et al* (1996).

" **UCPE nested quadrat method**

This method was developed by the UCPE at Sheffield University in conjunction with the Peak Park Planning Board and English Nature (Hodgson *et al* 1995). Temporary 1 metre square quadrats are recorded at random locations within strips (ie strata) across a field or large plot. Each quadrat is subdivided into a nest of six cells, beginning at the bottom left-hand corner (10cm x 10cm, 20cm x 20cm, 30cm x 30cm, 40cm x 40cm, 50cm x 50cm, 1m x 1m). The sequential examination of the cells encourages systematic searching of the quadrat, while the different scales of the cells allow less common species to be picked up in the larger cells. The cell size in which a species is first encountered is recorded and it is not re-recorded in larger cell sizes. Frequency is again used to measure relative abundance and changes over time (see Leach & Cox 1995 for an example). Analysis can make use of the occurrence of species in different cell sizes over time (Hodgson *et al* 1995) although to date no attempt has been made to use the data in this way. Recording of a reduced list of species to exclude those difficult to identify has also been done in some cases. When recording a reduced list of species, 40 to 80 quadrats per day have been covered, or if all vascular plants are listed then 20 to 40 quadrats per day have been done, depending on the richness of the vegetation (S.J. Leach, English Nature, pers. comm.). To date, 40 quadrats per monitoring area have usually been done but it should be noted that if analysis of individual species frequencies over time is envisaged, then change could be quite large (perhaps around 30 per cent) before it would be found to be statistically significant, depending on the 'confidence' level required.

" **ADAS stand method**

This method has been produced by ADAS in response to the need to monitor ESAs. A permanently marked stand is randomly located in a site. The stand is usually 8m x 4m in size, and subdivided into 32 'nests', each 1m x 1m (Critchley 1997). These nests are themselves subdivided into 10 cells of increasing size in much the same way as the UCPE quadrat except that the cells approximately double in area from the bottom left-hand corner (6cm x 6cm is the size of the first cell), with a point in the centre of this cell representing the smallest 'cell'. As with the UCPE method, the smallest cell size in which each species occurs is recorded. The rationale for having one stand per site is rather different to completely site-based monitoring where change within the site is of primary interest. A range of ADAS stands are recorded across an ESA because here it is changes within the ESA that are of interest, ie it is the 'site'. The permanent stand has the advantage that changes recorded will be real, subject to observer error. Long, thin stands are an alternative layout where trampling within the stand is likely to be a problem, eg on wet ground (C.N.R. Critchley, pers. comm.). Differences in species frequency over time are calculated using the 'optimal scale', ie the cell size where change in that species will be most noticeable, which is around 50 per cent frequency (Critchley and Poulton 1998). All identifiable vascular plants are recorded. Interestingly, ADAS has found that there is not much difference in the consistency of recording among different plant groups, eg dicotyledons versus monocotyledons (Poulton and Critchley, unpublished). Usually one stand can be recorded in a full day (C.N.R. Critchley, pers. comm.).

15.7 Analysis and interpretation

15.7.1 Introduction

Quantitative monitoring results can be analysed on an individual species basis or as species groups, either a pre-defined selection or a multivariate investigation involving all species (eg Gibson & Brown 1992). Ideally, the advice of a statistician should be obtained and the method of analysis should be decided at the start, before data collection begins. Reference works on analysis techniques include ter Braak (1987), Scheaffer *et al* (1990), Sokal and Rohlf (1995) and Watt (1997).

The analysis of changes in species composition and abundance still leaves unanswered the question of what the results actually mean for managers trying to understand change and decide what action to take. Recently there has been considerable effort expended on ways to interpret floristic change. Several different approaches are converging on trying to characterise species by their ecological attributes or 'functions'. For example quick-growing species found on nutrient-rich substrates might be termed 'ruderal' species or plants found only on lime-rich soils identified as 'calcicoles'. The main current ways of describing such attributes are outlined in this section.

15.7.2 Ellenberg indicators

In a classic work on the vegetation of central Europe, Ellenberg (1988) listed characteristics such as soil reaction (acidic to basic) and water regime (dry to wet) for a wide range of species. Within each characteristic, a value or score was assigned to a species according to its ecology. For example, the 'water value' for *Aira caryophyllea* (silver hair-grass) is 3 (dry site), while that for *Caltha palustris* (marsh marigold) is 8 (damp to wet site). It should be remembered that these subjective scores relate to continental Europe and species may not behave exactly the same in more oceanic Britain. However, the lists have been found to be useful here (Mountford & Chapman 1993) and they form part of the ADAS 'suited species' approach (see section 15.7.5).

15.7.3 The ecological flora database

This database is being developed at York University (Fitter & Peat 1994) and incorporates information published in the Biological Flora accounts of individual species of the Journal of Ecology. The database also includes other information, eg from floras, about the ecological characteristics of species, and an on-line computer version is available under the Bath University Information and Data Service (BIDS).

15.7.4 Comparative plant ecology

Professor Grime and his co-workers (Grime *et al* 1988) at the Unit of Comparative Plant Ecology at Sheffield University have developed an approach whereby measurements of attributes of particular species, such as growth-rate and life span are combined to improve understanding of how species behave and to predict change in vegetation. This functional analysis includes categorisation of species into 'strategy' types, eg competitors or stress-tolerators. For example, creeping thistle (*Cirsium arvense*) is defined as a fast-growing competitor favoured by nutrient-rich conditions while heath bedstraw (*Galium saxatile*) is a slow-growing stress-tolerator and is favoured by low nutrient conditions. Increase in the proportion of species with a 'competitor' strategy might indicate eutrophication and/or neglect. A database called FIBS (Functional Interpretation of Botanical Surveys) facilitates the analysis of vegetation by strategy type and ecological attributes (Hodgson *et al* 1995). Examples of the use of the FIBS approach to interpret vegetation change are given in Leach *et al* (1997) and Byrne *et al* (1991).

15.7.5 Suited species

ADAS has developed an approach to aid the interpretation of results from ESA monitoring. It utilises information available from the above three sources together with additional information to characterise species 'suited' by different conditions, eg calcareous soils or grazing management. Allocation of species to these different categories is made using formalised 'rules' which allow the decisions on which categorisation is made for any particular species to be clear and consistent across species (Critchley 1996, Critchley *et al* 1996). An example of the use of the approach is illustrated by a report on the botanical monitoring of the Suffolk River Valleys ESA (ADAS 1997).

15.7.6 Hydrological regimes of species and communities

Silsoe College and the Institute of Terrestrial Ecology have been researching the tolerances of different plants in semi-natural grasslands to hydrological conditions, under contract to MAFF. The influences of hydrology are complex, as plants may vary in tolerance to waterlogging but also in susceptibility to drought. Early results of the work are described in Gowing & Spoor (1998) and Gowing & Youngs (1997). The quantitative information obtained should be helpful in monitoring wet grasslands and in guiding their hydrological management. It will also contribute to the broader scale characterisations of ecological attributes of species referred to in previous sections.

15.8 Causes of vegetation change: environmental factors versus management

The understanding of floristic change can be assisted by some type of functional analysis of ecologically relevant attributes of individual plant species, as described above. This analysis can point to specific causes of change that are related to management, eg increasing nutrient levels or undergrazing, although these causes themselves can be interrelated. However, direct recording of environmental factors may also sometimes be necessary to identify cause, eg water levels, soil chemistry or soil compaction. This is particularly the case where different causes produce similar floristic outcomes, for example on one Somerset site, drought effects were initially misinterpreted as over-grazing effects (S.J. Leach pers comm.). Of course, normally only experimentation will unequivocally establish the factors driving vegetation change, rather than just observing correlations between, for instance, management and floristic change.

Among factors outside management control, the weather has a particularly significant effect on grassland species composition and abundance and may underly much of the variability found from one monitoring period to another. A wet spring can produce a grassy sward while a drought might favour short-lived, low-growing species. It is often useful to obtain weather data, especially where considerable resources are being devoted to vegetation monitoring. Other wide-scale effects include atmospheric deposition and global warming. The linking of monitoring sites into a network would provide a context for site-specific change as is the case for the Butterfly Monitoring Scheme (Pollard & Yates 1993). The UK Environmental Change Network (Sykes & Lane 1996), which has been in operation since 1992, includes several grassland sites where vegetation and environmental factors are recorded and may help to provide reference points.

15.9 Recording management activity

Ideally the site manager should record where and when key activities occur that are likely to affect the conservation interest of the grassland. These key activities are usually one or more of the following:

Hay making/mowing/topping including dates and sometimes number/size of bales
Grazing intensity/stocking rate
Grazing period
Supplementary feeding
Stock type
Timing of application and rates of inputs such as farmyard manure and lime
Rolling and chain harrowing
Drainage work
Raised water levels including period of flooding and depths
Burning
Control of invasive species and noxious weeds
Rabbit control

Sometimes it is useful to monitor how different parts of a site are being grazed by free-ranging animals, including rabbits, to assess their effects. Putman *et al* (1991) describe a study of the patterns of use by cattle and horses on common land. A rectangular grid divided into squares was drawn on maps to cover the sites and located on the ground by using landmarks. On one site each square was about 3.8ha and the other was 0.36ha. Visits were made every day or so and the number of livestock counted in each grid square at, on average, three times during the day. Sykes & Lane (1996) describe an indirect method of estimating rabbit and deer populations by recording dung after previous clearance along a transect. Parer & Wood (1986) use counts of warren entrances as an index of rabbit number. MAFF's Central Science Laboratory uses spotlights to count rabbits directly at dawn or dusk and considers this to be the most reliable method (D. Cowan, MAFF, pers. comm.).

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