CHAPTER 2

REVIEW AND EVALUATION OF CURRENT MONITORING METHODOLOGIES AND SCHEMES

1 INTRODUCTION

In this chapter, the different botanical monitoring methods that have been applied in England and the rest of the UK are reviewed, along with related research on botanical monitoring methods. The results they produce are assessed in terms of their relevance to individual site, individual scheme and national policy objectives at the time of their application. Each method is assessed in terms of its relevance to the objectives of individual sites, individual schemes or existing national policy for AE schemes at the time of their application. Each method is also assessed as far as possible in terms of its scientific rigour.

A range of topics has been addressed in this review. Firstly, the current sampling and field methods used to date in English AE botanical monitoring programmes are reviewed. Methods used in the other UK countries are also examined and comparisons made with those in the English programmes. A review of the scientific literature relating to recent research on monitoring methods is carried out, and the relevance to AE schemes is considered. Methods used for detection and interpretation of change in AE schemes are also assessed, along with recent research on this. Datasets that might be used as potential ‘controls’ for the monitoring programmes are evaluated, and the use of environmental data for assessing drivers of vegetation change is assessed. The recent development of Rapid Condition Assessment (RCA) methods in the UK is also documented.

Each section is based around a table that summarises the information gathered from a variety of reports of monitoring agri-environment schemes. The contents of each table and the column headings are explained in each section and there is a brief summary of the findings. Tables are provided separately in electronic format.

2 MONITORING METHODS USED IN ENGLISH AGRI-ENVIRONMENT SCHEMES

2.1 AIM AND SCOPE

The aim of this review and evaluation is to bring together information on the methods used for the past and present monitoring of the English agri-environment schemes. The overall strategy is summarised in ADAS (1995), but information has been collated from individual monitoring reports to ensure that up to date details for each scheme are documented.

2.2 REVIEW TABLE

This review is presented as Table 2.1. The table is divided into the following columns:

A Endnote reference number

This gives the number in the Endnote database from which the information in the row has been collated.

B Scheme

This column gives the scheme for which the report was written and in which the survey was carried out.

C Monitoring Organisation

This column gives the organisation(s) that carried out the project from which the information was gathered.

D Habitat

This column lists the habitats that were surveyed.

E-F Sampling Strategy

This column describes the sampling strategy and is split into two separate fields. The first field describes the sample size and distribution and the second field describes the sampling strategy at each site visited.

G Population of which sample is representative

This column indicates the population i.e. scheme or part of scheme that the sample represents. Parentheses indicate that the sample was believed to be representative by the authors, but was in fact subjectively chosen.

H Field Method

This column describes the method used in the survey. Some methods were generic in their application, having been used in several schemes or several habitats. They have been published and are included in the Endnote database that accompanies this report. The generic methods were:

ADAS plot method for grassland (Critchley & Poulton 1998)
Countryside Survey method (Bunce & Shaw 1973)
Transect line (Smith *et al.* 1985)
GI/BU method for heather grazing assessments (Poulton 1991)
Ditch survey in 20m strips (Alcock & Palmer 1985; Morris *et al.* 1993)

I Quadrat/plot size

J Years sampled

This refers to when sampling took place.

K Duration (years)

This refers to the length of time for which the scheme was monitored. In some cases only part of the sample was resurveyed. A zero in this column denotes a single survey rather than monitoring over a period of time.

L Fixed Unit

A fixed unit is the lowest level in the hierarchy of fixed locations within which repeated measures are made (e.g. a fixed quadrat).

M Environmental data

This column gives the additional environmental and management variables that were measured or assessed for each quadrat/plot.

N-O QA on data collection/ QA on data entry

These columns give the quality assurance (QA) protocols applied to the survey and its data. This column is only filled in if QA was mentioned in a report. An omission therefore reflects either an omission in a report or a lack of QA.

P Ease of relocation of sampling point

An indication of whether the quadrats can be relocated is given in this column. A "?" in the table denotes that there is no mention whether fixed plots were marked permanently. The use of the word "possible" in the table means that relocation of plots can be achieved.

Q Format of current data archive

This column lists the software or hardcopy status of the archive for the data.

R Classification System

This column lists the classification system(s) on which the data archive is based.

2.3 OVERVIEW OF TABLE CONTENTS

2.3.1 Grassland

Grassland habitats have been monitored in land within Environmentally Sensitive Areas (ESAs), the Habitat Scheme and the Countryside Stewardship Scheme (CSS), and have been monitored in terms of plant species composition and the characterisation of plant communities.

ESAs were the first of these schemes, introduced in 1987, with following rounds in 1988, 1993 and 1994. Botanical surveys began in 1987, with the first rounds of ESAs resurveyed after a maximum of eight years, using sampling strategies driven by local objectives, and often requiring subjective selection of fields. The vegetation plots also varied in size though tended to be the same for all ESAs introduced at a given date (see also reviews by Critchley (1997), and, for lowland grasslands, Burke & Critchley (2001)). The original method involved using five 2m x 2m quadrats along a transect (following Smith, *et al.* 1985), to be replaced by the 'ADAS plot' method for those

ESAs introduced in 1993 and 1994. This involved using plots of 8m x 4m consisting of 32 cells and 10 nests within each cell (Critchley & Poulton 1998).

Surveys of former set-aside land and water fringe areas of the Habitat Scheme used small quadrats of 1m x 1m and 0.5m x 0.5m respectively (ADAS 1998i; McLaren 1998). By contrast, the survey of CSS agreements was designed to be comparable with Countryside Survey (CS), requiring the mapping of habitats using the then-new system of Broad Habitats, and using a $200m^2$ nested quadrat per agreement, with additional quadrats within parcels of Priority Habitats (Carey *et al.* 2001a). Data were classified in terms of the Countryside Vegetation System (Bunce 1999), in addition to the National Vegetation Classification (Rodwell 1991 *et seq.*) used for other surveys.

2.3.2 Heathland

Heathland habitats pose particular problems for monitoring, partly because of the complex, patchy nature of the vegetation, and partly because assessing grazing and heather burning is important to understand likely trends in vegetation, especially the changing balance between dwarf shrubs and grasses (Gardner *et al.* 1998). Therefore, surveys for the Moorland Scheme and ESAs have involved several approaches in addition to conventional quadrats. They included aerial photographs to assess heather cover and heather burns (ADAS 1997b; ADAS 1997c; ADAS 1997i; ADAS 1997l); vegetation plots within fenced and unfenced areas to assess effects of grazing and progress of restoration (ADAS 1996g; ADAS 1997b; ADAS 1997c); and other measures of heath condition, including distance to palatable grasses and heather height, cover and age (ADAS 1997c; ADAS 1997h; ADAS 1997i; ADAS 1997l; ADAS 1998f; ADAS 1998j). Grazing has also been monitored using analysis of heather shoots; the percentage of shoots grazed on sample stems was used to generate a Grazing Index (GI), that was converted to a Biomass Utilisation (BU) estimate that could be compared against known grazing thresholds for different heather growth stages and types (Poulton 1991).

2.3.3 Arable

The monitoring of arable habitats within the Habitat Scheme (Water Fringe Areas), Breckland ESA and the Arable Stewardship pilot scheme has concentrated very much on the use of quadrats within particular features managed for wildlife within and around the arable fields. These include uncropped wildlife strips (ADAS 1997a), conservation headlands (ADAS 1997a), and the range of sub-options within the pilot Arable Stewardship scheme, including overwinter stubble, spring fallow, undersown cereals, grass leys, conservation headlands, no-fertiliser conservation headlands, sown and naturally regenerated grass margins, uncropped wildlife strips and wildlife seed mixtures (Critchley *et al.* 2001). The size and shape of the quadrats is strongly influence by the dimensions of the features being studied.

2.3.4 Ditches (dykes/rhynes) and banksides

Monitoring of ditches and banksides has involved assessing plant species occurrence and cover along lengths of the water courses using methods based on Alcock & Palmer (1985) (McLaren 1998; ADAS 1991a; ADAS 1991c; ADAS 1991d; ADAS 1996b; ADAS 1997j). In the Broads ESA, vegetation was characterised within four zones (submerged, floating, emergent and bank). Selection of the sample locations has involved both random and subjective methods.

2.3.5 Saltmarsh

Saltmarsh vegetation consists of complex and dynamic mosaics. Monitoring programmes have tried to encompass this large scale complexity by mapping sites according to the NVC as well as using quadrats (ADAS 1998b; McLaren 2001a; McLaren 2001b; Sherwood, 2001; McLaren 2002).

2.4 EVALUATION

2.4.1 Sampling

In most cases the aim was to take random stratified samples of sites in the scheme, with the stratification being based on factors such as entry into scheme tier, geographical location, soil type and level of agricultural improvement. However, this was sometimes thwarted by practical difficulties caused by insufficient numbers of sites, or sites changing tier or entering or leaving the scheme. In the earlier schemes (Stages 1 and 2 ESAs), sites often had to be selected subjectively. In these cases, sites were treated as case studies. Therefore, the extent to which samples are truly representative of the target vegetation type varies between schemes and between monitoring programmes. In general, random or stratified random sampling in the later schemes ensured that sampling was statistically valid, and where sample sizes were adequate the samples are representative of the target vegetation types. In the majority of cases, initial sampling was done in the first year of operation of the schemes. Samples of agreement land might therefore be biased if agreements signed in the first year differ from those entering subsequently, although the magnitude and nature of any bias is not known. An appraisal of the representativeness of each sample is provided in the table. The implications of this for future monitoring will be dependent on new monitoring objectives, and will be addressed later.

2.4.2 Quality assurance

The main contractors that have carried out botanical monitoring to date are ADAS and CEH. ADAS operates an internal Quality Assurance (QA) scheme that was introduced in 1997, which ensures that data are checked in the field and at data entry. In addition, all data collected for AE scheme monitoring have been checked in this way from the outset. QA carried out on Stage 1 and Stage 2 ESAs is well documented in the monitoring reports (see table). Although less detail is provided in other reports, the same procedures are believed to have been followed. Appropriate automatic data validation facilities have been used on electronic databases. The QA, therefore, is considered to be adequate.

Of the work carried out by CEH, CSS data were double punched (i.e. entered twice to trap errors of mis-typing). Anomalies between the GIS created by MAFF and the GIS created by CEH were checked by surveyors.

QA measures by other contractors have not generally been documented in the monitoring reports (see table).

2.4.3 Duration

Rate of vegetation change depends on many factors, including management, so it is difficult to predict the necessary duration of a monitoring programme and the optimum frequency of survey. Rehabilitation can be slow whilst degradation can happen rapidly. In lowland grasslands in ESAs, few beneficial changes were detected in monitoring programmes of up to 8 years' duration (Burke & Critchley 2001). On heathland in Northumberland under ESA prescription, changes at a community and species scale were detected after 6 years (Adamson *et al.* 2001). On moorland in Dartmoor ESA significant changes in heather frequency, grazing suited-species score and vegetation height were detected after 3 years (ADAS 1998j). Generally, the longer a monitoring programme has been running, the more valuable is the dataset for future monitoring of a given vegetation type, especially if several surveys have been carried out. The longest time intervals between first and most recent surveys to date are 8 years for some grassland monitoring programmes in the early ESAs. However, it is now possible to detect change over even longer timescales by relocating quadrats originally surveyed in the early rounds of ESA monitoring.

2.4.4 Ease of relocation

Most of the survey sites can be relocated, and it should also be possible to relocate fixed quadrats that have been marked with buried metal pipes or plates and have had maps drawn to assist relocation. In many schemes, fixed units have been already been relocated for repeat surveys. Success of relocation has depended on the quality of the individual maps and on the substrate (pipes in peaty soils are less stable than those in mineral soils). In general, the longer the time since the last survey, the more likely there are to be difficulties in relocation. The use of GPS systems in the future should make relocation of plots faster and more accurate.

2.4.5 Data

Data held on the AEMA database are readily accessible. All other data are accessible in electronic form, with the exception of the large dataset from the Lake District ESA rough grazing. Database maintenance and management are required to maintain accessibility, which is more at risk with software systems that tend to change data formats frequently.

3 MONITORING METHODS USED IN AGRI-ENVIRONMENT SCHEMES IN OTHER UK COUNTRIES.

3.1 AIM AND SCOPE

The aim of this section is to review methods used for collecting botanical monitoring data in AE schemes in the UK countries other than England. Methods are compared with those used in English AE schemes and their compatibility with existing methods is assessed.

3.2 REVIEW TABLE

The columns in Table 3.1 are essentially as described in Section 2.2, except that Country is recorded, and information on data quality and sample relocation is not considered relevant.

3.3 OVERVIEW OF TABLE

3.3.1 Scotland

Scottish ESAs were monitored in two phases. The first phase was carried out during 1989 – 1993, across a very wide range of habitats including woodlands, moorland, grasslands, wetlands, arable and machair. In general sites were selected using stratified random techniques, and vegetation was recorded using permanent quadrats (1m x 1m or 2m x 2m depending on habitat) located along transects (Henderson *et al.* 1994a; Henderson *et al.* 1994b; Nolan *et al.* 1994). In 1994 this was replaced by a new monitoring programme designed to assess changes in extent as well as composition of vegetation communities (Cummins *et al.*. 1997; Gauld *et al.* 1997; Cummins *et al.* 2000). Background monitoring was used to measure vegetation change in the ESAs, irrespective of agreement status. This involved selecting 1km squares within each ESA, which were mapped, and fixed quadrats established according to (slightly modified) CS protocols. Prescription monitoring was used to measure vegetation change on land under Tier 2 agreements. For each Key Vegetation Type, up to 30 plot locations were selected from all the possible Tier 2 areas, and vegetation recorded as for background monitoring.

3.3.2 Wales

Monitoring for the Welsh ESAs followed much the same pattern as for those in England. From 1987-1993, the quadrat method was used in the first Welsh ESAs. In 1994 the monitoring was reviewed and restarted (ADAS 1997m; ADAS 1998a; ADAS 1999a; ADAS 1999b; ADAS 1999c; ADAS 2000a; ADAS 2001a) using the ‘ADAS Plot’ methodology (Critchley & Poulton 1998). Again, as in England, heather grazing was assessed using the ADAS grazing index and biomass utilisation (GI/BU) method (Gardner *et al.* 1998). In woodlands in the Cambrian Mountains ESA, saplings and seedlings were identified in permanent quadrats located along transects.

The monitoring of the Tir Cymen scheme was superficially more similar to CS because of the range of plot types. Species data were collected from species plots (either 2m x 2m in areas of homogeneous vegetation structure or $200m^2$ in more complex stands), boundary plots were used for measures such as height and dominant tree and shrub species, and cover plots were used to record vegetation height, cover and dominant species (Entec 1997; Entec 1998). Non-agreement farms were included in the survey. The monitoring for the new Tir Gofal scheme has not been finalised (ADAS 2001b), but the proposal is that it will run from 2001-2013, including 5 years of baseline surveys followed by repeat surveys at the 4 and 9 year point. The field survey methods will include a modified Condition Assessment (see Section 9 for more details) including the use of quadrats of variable size (K. Austin *in litt*. to RDS).

3.3.3 Northern Ireland

Monitoring in Northern Ireland ESAs includes heather moorland, woodland, grassland, hay meadows, hedges and ditches. Monitoring began in 1993, using methods similar to those used in the Stages 1 & 2 English ESAs (Smith *et al.* 1985). Similar methods are likely to be used for the Countryside Management Scheme (Johnstone 2001).

3.4 EVALUATION

In order to address the specific objectives of each monitoring programme, sampling strategies have varied widely both between countries and across different schemes within each country. Comparisons with English schemes have therefore been focussed on field recording methods.

3.4.1.1 Grassland and related vegetation types

Overall, there is some consistency in the grassland field methods that have been applied in the different UK countries. The quadrat method used in the earlier English ESA monitoring programmes was also used in the discontinued monitoring programmes in both Scotland and Wales. It is also being used in Northern Irish ESAs and will be applied in CMS. A slightly modified version is also used in grassland and wetland in the current programme for Scottish ESAs. This method has the strengths that it can detect change through time and is widely applicable across different habitats. Its main weakness is that extrapolation to whole ESAs was not always possible. The more recently developed 'ADAS plot' method has also been used in all Welsh ESAs since 1994. The main strengths of this method are that it was better at detecting change than other quadrat or plot methods. Its main weakness was the length of time required to carry out individual quadrat assessments.

Grassland assessments in CSS and Scottish ESAs were done using Countryside Survey methods, so that comparisons could readily be made with the wider countryside. The other main strength of this method was the speed of doing the nested quadrats. The weakness of the method was that only one quadrat per habitat was carried out.

Different approaches have been taken in Tir Cymen and Tir Gofal. The weaknesses in all of the methods were created because of financial constraints on those carrying out the surveys.

3.4.1.2 Heather Moorland

The GI/BU method applied in English ESAs was also used in the Cambrian Mountains and Preseli ESAs in Wales. Various methods have been used in other schemes to measure grazing intensity, species composition and vegetation structure. No method has yet been devised to assess moorland quality adequately. Moreover, detecting vegetation change has proved difficult, because of the twin requirements to monitor quite large patches of vegetation and defining them well enough to be able to record change. Experience from CS suggests that mapping vegetation patches in unenclosed land is prone to errors of an equivalent scale to the likely changes between surveys; as a result, small, relocatable plots have been introduced to help monitor moorland change.

3.4.1.3 Woodland

The survey of the English Farm Woodland Scheme (FWS) and Farm Woodland Premium Scheme (FWPS) was focussed on species composition in 2m x 2m quadrats. Comparable data have also been collected from Scottish ESAs (in both first and second phases of monitoring). In other schemes, different quadrat or plot sizes have been used, although in Northern Irish ESAs species data have also been recorded from a 2m x 2m nest within a larger plot. However, data on tree regeneration have been collected from all schemes apart from the FWS/FWPS. The weakness of this method is that 2m x 2m is often considered too small to adequately monitor woodland (the reason why CS quadrats are so large is to adequately monitor woodland plots).

3.4.1.4 Other habitats

Methods used for monitoring of other habitats, as in the English AE schemes, have tended to vary according to the specific objectives of the monitoring programmes.

4 RESEARCH ON MONITORING METHODS

4.1 AIM AND SCOPE OF THE REVIEW

This review covers research carried out to develop field methods for collecting botanical monitoring data. Descriptions of monitoring studies where novel methods have been applied, and might be relevant to AE schemes are also included. Literature searches were carried out using the DialogSelect™ electronic database. Unpublished research reports were also reviewed where relevant.

4.2 REVIEW TABLE

A description of research papers examining botanical monitoring methods in AE schemes is presented as a table in which papers are grouped by research theme (Table 4.1). This table also provides details of the parameters measured, the method used, and the results of the research.

4.3 OVERVIEW OF THE TABLE

Different methods have been developed and used for a variety of different scales, sample sizes and most importantly for different objectives. Some parameters and techniques that have been examined for use in monitoring the botanical characteristics of AE land are:

Species presence and abundance
Grazing pressure
Sward height and structure
Near infra-red reflectance spectroscopy
Remote sensing

4.3.1 Species presence and abundance

Botanical survey methods that measure the relative importance of different species in vegetation samples are described in many textbooks e.g. Kershaw & Looney (1985); Causton (1988); Goldsmith (1991). Examples include methods for measuring density, cover, biomass, performance and frequency. However, these methods (described in Table 4.1) have been developed to describe rather than monitor vegetation and are often limited in their use when trying to detect small changes over time (Dallmeier *et al.* 1992), not least because different species need to be monitored at different scales in order to detect change (Greig-Smith 1983).

Estimates of cover by eye, including those made on the Domin or Braun-Blaunquet (relevé) scales, are insensitive to small changes and observer variation is high unless work is carried out by pairs of observers (Nilsson 1992; Poulton & Critchley unpubl.; Poulton, *et al.* unpubl.).

Frequency measurements within quadrats are less subjective, and have been modified to overcome the problem of monitoring over different scales by using nested quadrat designs, in which vegetation is recorded within subsections of the quadrat of increasing size (Bunce & Shaw 1973; Winward & Martinez 1983; Maslov 1990;

Hodgson *et al.* 1994; Critchley and Poulton 1998). For example, the standard main quadrat of CS (Bunce & Shaw 1973) is nested, with each nest centred on the same point. The outer quadrat is 200m^2 (14.14 x 14.14m), there are four more smaller quadrats with the smallest being 4m^2 (2 x 2m). The percentage cover of each species is noted in the inner quadrat. Additional species are noted in the innermost quadrat in which they appear, and the species cover within the largest quadrat estimated by eye. The 'ADAS plot' method (Critchley & Poulton 1998) is similar, but is based solely on species' presence, thus increasing precision by avoiding the use of subjective cover estimates. The fixed unit is a plot consisting of 32 subunits (nests) arranged contiguously in an 8 x 4 grid (usually 8m x 4m). Each nest consists of nested cells of increasing size, in which species are recorded cumulatively. This includes an estimate of top cover using pin hits.

Hodgson *et al.* (1994) developed a method capable of dealing with larger scales by dividing the area to be monitored into five strips. In each strip, six 1m x 1m quadrats were randomly located; each quadrat consisted of a series of nested quadrats in which species were recorded cumulatively. It is suitable for monitoring individual fields, especially where within-field spatial variation in the vegetation is not high. However, a large sample of quadrats would be required if small changes in the vegetation were to be detected.

All nested quadrat methods address the problems of recording a wide range of species with varying scale and pattern of spatial distribution, and inter- and intra-observer variation are reduced considerably in comparison with subjective cover estimates. However, as with all quantitative methods, it can be labour intensive, taking up to 2-3 staff days to relocate and record a single plot. There is a balance between recording effort and survey effectiveness; Burke & Critchley (1999) found that 16 nests each containing 10 cells was adequate in most cases and would reduce the monitoring time, on each plot, by 40% compared with the usual ADAS nested plot.

Methods used specifically for monitoring changes in plant communities in heathland vegetation in recent DEFRA (MAFF) funded research projects, at species and community levels, have been described and assessed (Gardner *et al.* 1999). Methods included various cover and frequency techniques. Of the methods tested, it was concluded that first hit using cross-wires was the most consistent and sensitive technique, though it was not good at detecting understorey vegetation or species present at low densities.

4.3.2 Grazing assessments

Many of the AE schemes have prescriptions that are designed to enhance floristic diversity by controlling grazing. Estimating the intensity of grazing is therefore of some importance. For upland moors and heaths, methods to assess the utilisation of dwarf shrub and graminoids by grazing animals were initially developed in the UK by the HFRO and latterly the Macaulay Land Use Research Institute (MLURI). Shoots were allotted subjectively to one of four classes and an arbitrary weighting (in brackets) given to each grazing level (Grant *et al.* 1976):

(i) removal of leaf/shoot tip (0.25)

(ii) less than half leaf/shoot removed (0.5)

(iii) more than half leaf/shoot removed (0.75)

(iv) grasses grazed to stubble, heaths grazed to previous season's wood (1.0)

This method was adapted in later studies to apply only to heather shoots. The first class (removal of shoot tip) was abandoned and weightings were amended (Grant *et al.* 1981). In another study, grazing on *Nardus* was estimated by counting the number of grazed tillers out of a random selection of tillers (Grant *et al.* 1996).

An alternative method to measure grazing on heather was developed specifically for English AE schemes, to reduce the problems encountered by inexperienced observers when required to make subjective judgements in the field (Poulton 1991). This method involves only the collection of a random sample of heather shoots in the field. In the laboratory, the proportion of grazed shoots is counted (Grazing Index). This is then converted to a value of Biomass Utilisation. However, this method has been described and criticised under MAFF contract BD00114 (Gardner *et al.* 1998). The relationship between the Grazing Index and Biomass Utilisation, and the threshold levels used for measuring suppression of heather growth by grazing, were based on data collected from a restricted set of environmental conditions, and so the validity of applying them elsewhere is uncertain (Kirkham & Wilson 2000; Gardner *et al.* 1998). In addition, the validity of the statistical method used for converting Grazing Index to Biomass Utilisation has been questioned (Kirkham & Wilson 2000).

4.3.3 Sward height, structure and other characteristics

Kirkham *et al.* (2001) reviewed and assessed methods to be applied in AE schemes for estimating sward characteristics such as height, structure, bare ground and litter. Methods of height measurements included (i) the HFRO sward stick (Barthram 1986), (ii) drop disc (Holmes 1974; NCC 1986), (iii) plate meters (Holmes 1974), (iv) ruler, (v) point quadrats (Grant 1993), (vi) electronic capacitance probes (Frame 1993) and (vii) visual estimates (which have also been used to estimate herbage mass).

The HFRO sward stick is a graduated stick with a sleeve from which projects a clear Perspex ledge. The sleeve is slid down the stick until the Perspex hits vegetation, at which point the vegetation height is recorded (Barthram 1986). The drop disc has a disc with a central hole, of specified diameter and weight, which is allowed to fall down a graduated stick; again, the height to which it falls is recorded (Holmes 1974; NCC 1986). Plate meters are similar to drop discs but are combined with an estimate of herbage mass (Holmes 1974; Frame 1993; Grant 1993). Methods (v)-(vii) are not commonly used. Recommendations of Kirkham *et al.* included using the HFRO sward stick rather than the drop disc as the best method for measurement of sward height.

Stewart *et al.* (2001) also compared measuring sward height with a ruler, the drop disc method and the HFRO sward stick. The sward stick gave the most variable results; it was the best method for measuring the architecture of the sward surface, but was less useful for measuring short swards. The drop disc method was not good for measuring sward architecture or short swards, but was useful for measuring productivity. The ruler method was suitable for short swards. The sward stick consistently gave the highest and the drop disc the lowest readings. For larger scale monitoring the drop disk is the most useful technique as it gives a good indication of height quickly in a variety of vegetation types. Obviously the required sample size varies greatly with vegetation type and management; the more uniform the vegetation structure, the more appropriate these methods are.

If data are to be compared with those previously collected, the method used in the previous study should be used. If information about sward heterogeneity is required, the HFRO sward stick is recommended. In other situations the drop disc has the advantage of having high observer consistency and being quicker to use than the sward stick as fewer readings are required.

4.3.4 Near Infrared Reflectance Spectroscopy (NIRS)

NIRS involves the scanning of dried samples of vegetation in terms of the properties of reflected radiation, and is commonly used in the food and agricultural industries (Osborne *et al.* 1993). Coleman *et al.* (1985) used NIRS to estimate the composition of grasslands which contained between two and four species, whilst a later study (Garcia-Criado *et al.* 1991) looked at the potential of NIRS to distinguish between species groups, e.g. legumes or grasses. The feasibility of using NIRS for assisting in monitoring species-rich grassland was investigated (ADAS, 1996h; Atkinson *et al.* 1996). Although it showed some promise, further work is required before the method could be applied to vegetation monitoring. Potentially, it could be used in conjunction with field surveys. It is unlikely that this method would be useful for monitoring changes in species composition of complex communities such as species-rich grasslands because the system is unlikely to prove sensitive enough to distinguish between all species. Moreover, conversion from the proportions of taxa within the samples to those in the field is sensitive to small variations in sample preparation, and to variations in moisture content of the vegetation.

4.3.5 Remote sensing

Aerial photography has been used extensively in English AE schemes to map land cover, and can provide a quick and permanent record of coarse vegetation structure over large areas (Hooper 1992). It is suitable for monitoring change on a large scale (e.g. heather cover (ADAS 1997b) or heather burning (ADAS 1997i)), but is not sensitive to small changes in patch size or vegetation structure. It is relatively inexpensive, considering the amount of data collected and can provide a wider context for more detailed ground surveys.

Satellite images record, in digital format, reflected electromagnetic radiation in a number of discrete wavebands (Budd 1991). Many of these bands have been specifically selected to maximise vegetation discrimination. The results of MAFF project BD0323 suggest that it is feasible to use satellite imagery to differentiate between grasslands of various levels of agricultural improvement (ADAS 1996a) whilst the results of a Japanese study suggest that satellite imagery can be used to monitor the status of grassland management (Mino *et al.* 1998). CEH investigated the use of aerial photography and satellite imagery to identify NVC communities on Salisbury Plain with limited success (Gerard *et al.* 1999). This technique could be useful to provide broad descriptions of grassland over wide areas and, like aerial photography, could be used in conjunction with ground surveys. The CEH Land Cover Map uses Landsat imagery to identify land cover classes comparable to many Broad Habitats with a pixel size of 25 m – too coarse for monitoring individual agreements, but suitable for monitoring changes within (e.g.) whole ESAs.

Low-altitude remote sensing (e.g. (Inoue *et al.* 2000)) could also be linked to ground survey, but this would require further development before being considered for vegetation monitoring in AE schemes. CEH and others are investigating the use of airborne CASI/LIDAR to identify vegetation types; this technology generates a fine scale digital map of the vegetation surface (with discrimination in height down to a few cm) and so, like aerial photography, can monitor changes in vegetation structure, rather than species composition. Its cost currently prohibits large scale use.

In general, remote sensing methods are not suited to monitor changes in species composition. However, they have great potential in monitoring habitat structure (e.g. heather mosaics, scrub encroachment, woodland gaps), which is important for many animal species, for example nesting birds. This is especially true in vegetation of non-uniform structure (including woodland and scrub) that cannot be well recorded using ground-based techniques.

4.4 CONCLUSION

There are relatively few examples of research specifically directed at botanical monitoring methods.

Species presence and abundance: There has been relatively little recent research on monitoring methods, although some development of the ‘ADAS plot’ method has been done since its first inception. Evidence from the literature clearly shows that cover estimates by eye are unreliable if observers work alone.

There are clear advantages of using nested systems compared with the single-scale methods of cover or frequency estimation, as they provide greater sensitivity to change for a wider range of species. They also allow for comparison across surveys even where the maximum quadrat sizes differ – either because of the dimensions of the habitats being surveyed, or the scale of spatial pattern within the vegetation itself – as long as there is a nest size in common (Barr 1997). Such systems have reduced observer variation compared with single-scale and subjective cover estimates, but still require skilled field botanists. It is unlikely that this need will be replaced by technological developments in the near future.

Grazing assessments: This is a specialised topic, and only two main approaches have been identified in this review. Currently, there does not appear to be a single ideal method for direct measurement of grazing intensity on plants. The MLURI method is suitable for use by experienced observers in cases where grazing intensity is not severe. There is also potential for the ADAS Grazing Index to be developed further for monitoring grazing on heather moorland.

Sward height and structure: Ground-based methods are available for grassland and other low vegetation types, but these are ill suited to more complex vegetation that includes scrub and woodland. Some remote sensing techniques show great promise for monitoring changes in vegetation structure, but are currently too expensive for routine deployment in AE scheme monitoring.

5 METHODS FOR DETECTING AND INTERPRETING CHANGE IN ENGLISH AGRI-ENVIRONMENT SCHEMES

5.1 AIM AND SCOPE

The aim of this section is to review indicators and analysis methods that have been used to interpret and detect change in land under English agri-environment schemes. The methods have been listed and characterised in terms of data requirement, interpretation and scope in Table 5.1, while the indicators themselves are evaluated in more detail in Section 7.

5.2 REVIEW TABLE

Table 5.1 shows the review results for the English AE monitoring schemes in terms of the monitoring objectives, the indicators used and the methods of data analysis used. The table entries identify key statistical issues and suitability for objectives, as well as other potential strengths and weaknesses of the monitoring programmes.

5.3 OVERVIEW OF TABLE

Because most of the field methodologies have involved collecting species data within quadrats, the data have been usually analysed and presented in terms of species diversity, vegetation character or appropriateness to the management objectives.

The ubiquitous measure of diversity has been the number of species per quadrat. Vegetation structure has been reported in such terms as height, bare ground and tussockyness for several schemes.

The vegetation data have been classified using one of four general approaches. The first is the NVC, which compares the vegetation with what are often subjectively defined stands of high quality vegetation. This is the most widely used classification, and has been applied to quadrat or plot data (sometimes after classification using TWINSPAN (Hill 1979), and has been used to map saltmarsh (ADAS 1998b). The second is the system of Broad and Priority Habitats introduced as part of the Biodiversity Action Plan. This is more appropriate for areas of land, rather than individual quadrats, and has been used for CSS (Carey *et al.* 2001a). Plot data may be classified into the Countryside Vegetation System (CVS), derived from a statistical analysis of plots from Countryside Survey; this classification is best regarded as a breakdown of the typical vegetation of GB and has also been used for CSS (Carey *et al.* 2001a).

The final general approach is to use some form of index reflecting the relationships between the plant species composition and the environment and management conditions in which the vegetation is found. The most frequently used is the 'suited species' system, whereby plant species are allocated scores against a range of environmental and management conditions, and indices derived from the species present in a sample. There are scores for variables such as grazing, low nutrient availability, high prevailing soil moisture levels, acidic soil, etc (Critchley *et al.* 1996b; Critchley 2000).

A further method to consider vegetation is to relate its character directly to environmental conditions using statistical approaches (such as Partial Canonical Correspondence Analysis (PCCA) (Ter Braak 1988) or ANOVA) that do not involve a prior classification of individual plant species characteristics. For the pilot Arable Stewardship Scheme, species distributions at the Pilot Area scale were predicted using models incorporated in a GIS (Sanderson & Staley 2001).

Change in vegetation has been assessed in a number of ways. The simplest is to consider trends in individual species or in indices derived from the species present. It is also possible to analyse changes in vegetation character in terms of changing towards some pre-defined endpoint, such as shifts towards a high quality NVC class or an increase in Ellenberg (Ellenberg 1979; Ellenberg 1988) or suited species Scores appropriate to management targets (Critchley *et al.* 1996a). In the Former Set-aside option of the Habitat Scheme, the SETSARIO model of community development in set-aside land was used to predict species distributions (ADAS 1998i). Monitoring change in uplands has also involved using indicators of grazing and condition noted earlier (Poulton 1991); in the Lake District ESA, mean BU was regressed against average stocking densities for each fell (ADAS 1997i).

6 METHODS FOR DETECTING AND INTERPRETATING CHANGE IN AGRI-ENVIRONMENT SCHEMES IN OTHER UK COUNTRIES

6.1 AIM AND SCOPE OF THE REVIEW

The aim of this section is to review the indicators used to detect and interpret change in vegetation in the other countries of the UK.

6.2 REVIEW TABLE

Table 6.1 summarises information from Scotland, Wales and Northern Ireland On the same basis as Table 5.1.

6.3 OVERVIEW OF TABLE CONTENTS

Generally, indicators used to detect and interpret change in vegetation monitoring schemes in other UK countries were similar to those used in the English schemes.

Most schemes used variables such as species richness, cover and height, with adaptations to specific habitats such as heather moorland (again addressing grazing) and woodland (addressing regeneration) (Henderson *et al.* 1994a; Henderson *et al.* 1994b; Nolan *et al.* 1994; ADAS 1998a; ADAS 1999a; ADAS 1999b; ADAS 1999c; ADAS 2000a; ADAS 2001a). Scottish studies have used controls, first with sites inside and outside ESAs, and subsequently with trends in CS data (Cummins *et al.* 2000).

Scottish and Welsh ESA vegetation data have been classified using suited species scores along with other measures, including Simpson’s diversity index (Cummins *et al.* 2000), and change reported in terms of individual species (Entec 1997; Entec 1998) and other categories, including the CSR system of Grime *et al.* (1988) (QUB 1993; QUB 1994; QUB 1997b; QUB 1998a; QUB 1998b; QUB 2000).

It has been proposed that monitoring of the Tir Gofal scheme should use a condition assessment method. In each habitat, data will be collected that are linked to particular objectives (e.g. in woodlands, number of seedlings and amount of dead wood). Target values will be set (e.g. 75% cover of dwarf shrub), and changes in the abundance of particular species assessed (ADAS 2001b).

7 RESEARCH ON METHODS FOR ANALYSIS AND INTERPRETATION OF CHANGE

7.1 AIM AND SCOPE OF THE REVIEW

The aim is to review research relating to indicators for assessing botanical changes. This has been extended to the wider scientific literature to understand how they have been used in different contexts. The strengths and weaknesses of each approach have been evaluated in the context of AE scheme monitoring objectives.

7.2 REVIEW TABLE

References used in the review are documented in Table 7.1. The different uses of indicators are demonstrated to assist in evaluating their effectiveness for measuring changes in vegetation condition. This summary relates to information in the table and to those indicators used in AE scheme monitoring programmes in England and other UK countries.

7.3 REVIEW OF METHODS

7.3.1 Suited species scores

The ESA schemes mostly use the suited species scores* method of vegetation quality assessment (Critchley *et al.* 1996a; Critchley *et al.* 1996b; Critchley 2000). Specific objectives have been set for each ESA for both maintenance and enhancement of vegetation types. Low intensity agriculture produces the preferred conditions for vegetation of conservation value, such as low nutrient availability and moderate grazing pressure. The goal vegetation can be defined as a specific biotope that is limited by a set of biophysical conditions. Species suited to specific conditions can be defined by applying rule sets to a matrix of species with their traits and habitat preferences compiled from a range of sources. Autecological information was compiled for vascular plants based mainly on those in Ellenberg (1988); Grime *et al.* (1988); Hodgson *et al.* (1995) and Fitter & Peet (1994). For each criterion a score is calculated as a measure of the relative contribution to the total vegetation of species suited to a specified condition. Suited species scores can be derived for each site or for each sampling unit. The scores for the G, Nu and W criteria were calculated as the difference between the scores for the extremes of the condition. Habitats assessed by suited species score include grassland, arable reversion, heathland, upland rough grazing, banksides, arable field margins and set-aside land.

Scores are calculated using presence/absence or abundance data (e.g. Domin, percentage cover). For an ADAS plot, the local frequency of each species at its optimum scale in the plot (defined as the scale at which its cumulative nest frequency is closest to 16) was used.

*suited species scores:
G- suited to grazing
Nu- suited to low nutrient availability
A- suited to acidic soil conditions

W- suited to high soil moisture content
P- suited to poached conditions
T- tussock forming
D- suited to disturbance
M- suited to high summer soil moisture deficit
C –suited to calcareous soil conditions

7.3.1.1 Strengths

Suited species scores have been used throughout the ESA monitoring to define the goal vegetation and to assess whether this goal has been achieved by comparing the proportions of suited species with the predicted values. They can also be used to measure change by assessing how the proportions of suited species have changed over time. Suited species scores are a repeatable, accountable method as rules for each criterion are defined and applied systematically. When tested, there was a good correlation between the judgements of experts and site scores (Critchley 2000).

Suited species scores can be used to predict variation in biophysical conditions between sites. The suited species scores were explicitly designed to be sensitive to ecological conditions considered ‘good’ or ‘bad’ in terms of specific ESA vegetation management objectives (e.g. G – linked to over- or under-grazing; W – linked to water levels; Nu – linked to consequences of fertiliser application). Hence there is a close relationship between suited species scores and site management. This relationship with management has been validated using independent experimental datasets (Critchley *et al.* 1999a). Other indicators also provide information on plant attributes and can be associated with environmental conditions (e.g. Ellenberg scores and CSR) but not all are so closely related to management issues. Suited species scores can also detect functional change in the vegetation additional to that explained by the direct effects of management applied (Critchley *et al.* 1999a).

The status of the vast majority of vascular plant species occurring in the UK has now been determined for this system, as far as existing autecological information allows. A number of alien and rare species are not included, but this could be achieved by adding the required autecological information to the species-trait matrix.

7.3.1.2 Weaknesses

Suited species scores are not based exclusively on plant traits (because of shortfalls in current knowledge), but also incorporate information on habitat preference and so rely on interactions between plants and environmental conditions. Some adjustments may be needed when applied in other geographical regions as habitat preference can vary in different parts of their range. The status of some species was modified for Scottish ESA monitoring to account for geographical variation in their association with environmental conditions. However, this is now less of an issue as the system has since been improved by regular extension and updating of the species-trait matrix. Variation in performance across different environments is seen across a range of traits and plant functional types (Weiher 1999) so this problem is a general one (see Ellenberg values below) and does not specifically affect suited species scores.

This method will be more successful in some habitats than others, for instance where a lot is known about the relationship between species assemblages and management strategies. In species-poor vegetation, change in a single species can have a large effect on scores. As with all indicators, careful interpretation of the nature of any changes might be necessary. For example, in the South Downs ESA, suited species scores were used to assess the reversion of arable land to calcareous grassland. Although the C score declined, this was not considered to be detrimental because it indicated a loss of calcicolous arable weeds, rather than a loss of desirable calcicolous grassland species.

Species for which no relevant autecological information is available are allocated neutral status. As with Ellenberg scores, bryophytes are not included.

7.3.1.3 Issues

How well do suited species scores measure change?

> The suited species scores are sensitive to change in environmental conditions. There may be some variation in their usefulness between habitat types and they are dependent upon the rules used to assign scores.

Can they be applied universally or are other methods such as Ellenberg scores more widely acceptable? Can they be used to compare with control data?

> They have been used mainly to assess whether specific management objectives are being achieved. They can also give a more generic impression of the relationship between species composition and environment, as Ellenberg scores do, and comparisons with control data could be made readily. However, there may be a trade-off, i.e. if indicators are explicitly developed to address particular objectives then these indicators might be less applicable as a common cross-scale and cross-biotope indicator of change, for example between control data and smaller-scale impact monitoring. If this is the case then it is unlikely that a catch-all indicator that achieves all objectives is ever possible.

What is their compatibility with JNCC common standards monitoring (JNCC 1998)? Would it be possible to define condition using pre-determined suited species scores?

> Suited species scores could be used to measure condition as they are closely related to the management prescriptions for a site. In a report validating condition assessment (Robertson *et al.* 2000) on calcareous grassland sites, detailed monitoring and condition assessment were carried out and compared. Sites with lower Nu suited species scores also had more community character species, and so could be said to be indicating favourable condition. In another study indicators were calibrated using data from English Nature grassland and other surveys (Critchley *et al.* 1999a; Fowbert & Critchley 2000). It was found that suited species scores could be used with other indicators to distinguish between sites of varying quality. For example Nu scores tended to be higher in damaged sites and low G scores were associated with under-grazing. A similar approach could be used to calibrate scores against pre-determined JNCC condition categories.

7.3.2 Ellenberg Scores

Ellenberg, in a series of publications (Ellenberg 1979; Ellenberg 1988; Ellenberg *et al.* 1991), defined a set of indicator values for the vascular plants of central Europe. These have now been derived/calibrated for the British Flora (Hill *et al.* 1999). The relation between Ellenberg values and a measured environmental variable has been calculated for a restricted range of habitats.

Although Ellenberg values contribute to the suited species scores they have not been widely used in measuring vegetation change in agri-environment schemes. However, they have been used in vegetation analysis of CS2000 data to detect trends, interpret change and also to assist in characterising CVS classes. In the wider literature they have been used in a number of ways to interpret vegetation – environment relationships, e.g. to look at historic data to suggest previous environmental conditions and to characterise a site in terms of environmental conditions.

7.3.2.1 Strengths

Ellenberg values have been characterised and tested in many European countries. In some cases this has involved re-classifying values. They have been widely used to compare ecological conditions across habitats and communities at different scales.

Values are available for all species in the GB flora. Ellenberg values relate species composition to environmental conditions in the plot. Some studies have combined physical measurements and plant Ellenberg values to:

study autogenic succession (Sorensen & Tybirk 2000);
indicate soil nutrient status by looking at vegetation (Wilson & Lee 2000);
gain knowledge of habitat quality by combining Ellenberg values with Habitat preferences and other functional traits (McCollin *et al.* 2000);
determine which species are available to the target community from a regional species pool by using them as a filter (Dupre 2000);
relate distance from an ancient woodland boundary and changing environmental conditions with species distribution and to achieve monitoring of SSSI change (Smart 2000);
assess subtle changes in ground flora vegetation resulting from a slight change in canopy cover.

They are a relatively sensitive method of detecting temporal and spatial change, which can be interpreted in the context of prevailing environmental conditions.

7.3.2.2 Weaknesses

Bryophytes are not included; indicator values do exist but have not yet been applied (Siebel 1993). The Ellenberg system does not take account of interactions between environmental variables. Species' distributions are controlled by a combination of environmental variables. Indicator scores tend to be inter-correlated, and so changes in one score may actually be the indirect result of changes in another environmental characteristic (e.g. increasing nutrients and decreasing cutting can both give rise to a taller vegetation stand that displays increased fertility and decreased light scores). Species are not always constant in ecological requirements, some have different indicator values in different parts of their range (Hill *et al.* 2000) reflecting differences in realised niche dimensions from one biogeographic region to another (see also above for suited species scores). This is also influenced by varying intensity of competition from other species under different environmental conditions. Indicator values summarise a complex of parameters associated with the factor of interest, so additional weighting with species tolerances might be required (e.g. species with pH optima near the extremes show narrow tolerances while species with intermediate pH optima show wide tolerances) (Schaffers & Sykora 2000). Ellenberg N values are only weakly correlated with soil parameters (Ertsen *et al.* 1998).

7.3.2.3 Issues

Can they be used to assess whether particular objectives have been met as successfully as suited species scores do?

They can be used to define current and predicted environmental conditions on a site and so do have a relationship to management objectives.

Can Ellenberg scores be used to compare with control data?

Ellenberg values are available for all species so can be readily compared with control data.

What is their compatibility to JNCC common standards monitoring? Would it be possible to define condition using pre-determined Ellenberg scores?

Ellenberg values could be calibrated against condition categories in the same way as for suited species scores.

7.3.3 Functional Interpretation of Botanical Surveys (FIBS)

This is a method for analysing functional changes in vegetation (Hodgson *et al.* unpubl.) based on the plant strategies developed by Grime (1979). Plant functional attributes (including CSR radii (Thompson 1994), canopy height and structure, regenerative strategies, flowering time, seedbank type) can be used to interpret the distribution and population dynamics of species and to predict the consequences of changes in their environment or management regime. The theory is based on three primary axes of specialisation in plant species – competitors, stress tolerators and ruderals. Competitive species are adapted to productive environments and where competition is the limiting factor. They tend to be perennials with high relative growth rates and large canopy structures. Stress tolerators are adapted to unproductive conditions and are slow growing and short lived. Ruderals are species adapted to productive but disturbed environments.

7.3.3.1 Strengths

This method can be used to interpret botanical composition and management regimes of plant communities by functional attributes. It is possible to use an incomplete dataset to gain some understanding of community function. Once species have been characterised the method is straightforward to use. Indices can be calculated using a database of functional traits, although it does require skill for interpretation (Hodgson *et al.* 1999). The method was used in a historical study to look at differences in weed floras associated with different scales of cultivation, related to differences between plots in the degree of fertility, disturbance and watering. Using functional attributes it was possible to discriminate between plots cultivated at different levels of intensity.

7.3.3.2 Weaknesses

Measurement of some species traits is difficult in practice, so data have been collected from the literature for a large number of species. There are many gaps in the current dataset; bryophytes are missing and information is not available for all species in the

GB flora. No account is taken of variation within species, for example variation in genotypes or in life-histories between locations. However, this also applies to other indicators reviewed here. CSR strategy theory is the only attribute in the FIBS system that identifies eutrophication. Current understanding of factors affecting regeneration are incomplete. There is an extensive literature arguing for and against this approach to vegetation analysis, and despite its strengths and utility in applied ecology, it has not gained universal acceptance. Wilson and Lee (2000) give a recent and incisive critique of CSR theory

7.3.3.3 Issues

FIBS data are not available for all species, restricting its current applicability.

Can FIBS be compared with control data?

Similar to Ellenberg scores - it is straightforward to apply trait data to control data provided there is a database of plant traits and strategies.

What is the compatibility of FIBS analysis to JNCC common standards monitoring?

CSR radius values have been calibrated against sites of known quality for a range of vegetation types (Critchley *et al* 1999a; Fowbert & Critchley 2000) and so could contribute to determining the condition of a site.

7.3.4 Species richness

Vegetation change may be conveyed in terms of the number of species present in sampling units. The advantage of this measure is its simplicity, although the interpretation of changes in species richness is not straightforward because the measure takes no account of the identity of the species concerned (Smart *et al.* 2002 in press). For some habitats (e.g. heathlands) an increase in species richness may be undesirable, depending on the identity of the species. Moreover, species richness per unit area is a function of plant size, and so can be misleading if the vegetation is undergoing succession to scrub or woodland. Species richness has been used as an indicator in most of the agri-environment monitoring schemes. It is easy to calculate and provided care is taken in interpretation, it can be a useful way of presenting otherwise complex information to non-specialists.

7.3.4.1 Issues

Should other measures of diversity that compensate for species composition (e.g. Shannon Weiner index) be used in preference to species number?

Changes in the diversity indices can be difficult to interpret, reflecting either a reduction in the number of species or a reduced evenness in species distribution.

How does species richness compare in compatibility with control data to other methods?

Mean number of species can only be compared between samples at a constant spatial scale. However, species richness at the constant scale of $1m^2$ has been calibrated against sites of known quality for a range of vegetation types (Critchley *et al.* 1999a; Fowbert & Critchley 2000).

7.3.5 Changes in Abundance of Individual Species

In most of the monitoring programmes, changes in the abundance of individual species were assessed. This makes use of standard botanical data, and is usually is relatively simple to analyse using univariate statistical tests. If the ecology of individual species is well understood, interpretation of change can be relatively straightforward. However, individual species might need to be given differential weightings, which is a subjective process. There may be too few records of the chosen species for statistical analysis. In species-poor communities (e.g. saltmarsh) it may be more appropriate to analyse individual species rather than community variables, as it might be easier to relate species change to plant community function than in more complex communities.

If an agri-environment scheme agreement has the objective to protect a particular rare species it would be logical to monitor that species in detail.

7.3.6 Indicator species

Changes in habitat indicator species can be used to detect change in the quality of a habitat. The indicators could be key species that characterise NVC communities, indicator species lists based on expert judgement, published plant community profiles, rare species, or food plants for animals. Notable changes in certain key species can provide a general indication of changes in quality.

This method is most useful for distinctive communities such as calcareous grasslands, where certain species are exclusive to the vegetation type. For communities comprising only generalist species, it may be more difficult to identify key indicators. There are difficulties with the choice of indicator species as this is usually subjective, with conflicting views from experts about which species ‘indicate’ a particular community. It is also necessary to decide how many such ‘indicator species’ are required to characterise a community (See Section 5).

One example is the use of salt marsh indicator species in the Habitat scheme. Species restricted to saline habitats were identified, and their contribution to the total vegetation calculated in the same way as suited species scores. There are relatively few saltmarsh species, and they form a distinct group that is readily identified.

7.3.7 Heather condition

A combination of methods have been used to assess heather condition, percentage cover, age and growth stage. A method was developed specifically for the English ESAs (Poulton 1991) to assess the impact of grazing on heather condition, which has been discussed in Section 2. This method involved collecting heather shoots, determining a grazing index (GI, percentage of shoots grazed) in the laboratory and calculating biomass utilisation (BU) using a calibration expression determined from a separate sample of heather stems. The BU estimates were then applied to suppression thresholds from previous studies by MLURI.

By measuring heather condition, the index has been used as an indicator of quality, and how it changed in relation to grazing prescriptions. Differences in BU have been investigated using ANOVA with the factors, year, agreement class, grazing unit and transect. Differences in responses among agreement classes were assessed by considering year x tier interactions and the significance of differences in proportions of suppressed quadrats using Fisher exact tests. The relationship of BU with environmental and biotic variables has been investigated using stepwise regression. Simple linear regressions have been used to regress stocking rate against BU. Spatial patterns in BU have been analysed using Mantel tests.

7.3.7.1 Issues

The method requires further development to address weaknesses that have been identified (see Section 4.3.2).

Can Grazing index and BU be compared with control data?

> In theory, it should be possible to compare these indices between agreement and control samples. However, this would require heather samples to be collected from control samples specifically for this purpose.

7.3.8 Indices derived from the ADAS plot method

7.3.8.1 Scale-based diversity indices

Ten indices of vascular plant diversity were developed, which were derived from records of species frequency, richness, scale and distribution within ADAS plots (Poulton 1999). These indices measured properties such as dominance, abundance, evenness and scarcity, without reference to species identity. These were selected from an original long list of 18 indices, following tests of their ability to discriminate between different NVC units, their sensitivity to change over time and their robustness to observer-induced variation. The indices were tested on a range of grassland and upland vegetation types. The indices were considered to have potential for describing community structure in terms of species scale, dominance and richness. They could also have potential for highlighting misclassification of NVC communities and for characterising unusual plots. They can also be used for detecting change in community structure that might not otherwise be detected using other indices. For example, two of the indices suggested that calcareous grassland in the South Wessex Downs ESA had become coarser over time, a trend not detected by analysis of species richness or suited species scores. It was noted that some further work might be necessary, including testing the predictive power of the indices on unseen data.

7.3.8.2 Indices of spatial dynamics

A ‘community stability index’ was developed, based on the consistency of species’ spatial locations within an ADAS plot between surveys (Burke *et al.* 2000). The index was tested and showed significant differences between community types. Arable plant communities were shown to be most dynamic in species composition whilst mires, heaths and acidic grassland were the least dynamic. Calcareous and mesotrophic grassland had intermediate index values. Analysis of changes in the index over successive surveys showed that vegetation recovering from major disturbances or flooding showed gradual increases in stability of composition over time, which concurred with the known changes that had occurred within the specific test datasets. The community stability index provides a useful measure of rate of change in species composition within ADAS plots, and could potentially be used to characterise rates of change for different vegetation types. This could also be useful when making decisions about the frequency at which vegetation surveys should be carried out within agri-environment monitoring programmes.

An index of consistency for individual species was also developed, based on continuity of nest occupancy within a plot between survey years. Its purpose was to measure the extent to which species that showed little change in frequency had changing spatial distributions within the plots. There were a number of constraints on the distribution of the index and the precision with which it could be measured. These constraints were associated with nest frequency in each survey year and the fact that there is an upper limit to a species' frequency in an ADAS plot. Taking account of these constraints, relatively few plots yielded data suitable for analysis. However, for a minority of plots it could provide a useful tool to determine the extent to which species populations are dynamic and therefore potentially sustainable.

7.4 DISCUSSION

There is no single best method of abstracting indicators of vegetation character from quantitative plot data. This is because different sets of variables can be used to indicate different attributes of vegetation in a sample. However, all of these variables are derived from the same data, and so are intercorrelated to a greater or lesser extent. Risks of data misinterpretation are therefore inevitable.

Some indicators tend to be interpreted in terms of intrinsic vegetation character. Species richness is a widely-used measure of diversity, but also requires careful interpretation. The FIBS approach provides a potentially powerful functional description of vegetation, although it requires expert interpretation and data are lacking for some species. By contrast, other indicators are used to interpret properties of the environmental and management context of the vegetation. Thus suited species scores are closely related to scheme objectives via the management prescriptions, and can also give a more generic impression of the extant environment. Ellenberg values also indicate the underlying environmental conditions, and can be related to scheme management and objectives. The dangers of mis-interpretation are probably less when these scores are used to indicate a measure of closeness to a desired state (this can be done at the site level) than if they are used to interpret causes of vegetation change (that requires data across very large scales).

All these community variables can potentially be compared with control data, and calibrated into JNCC condition categories. Change in individual species, and indicator species, can also be useful in specific cases. Current methods for measuring heather condition require further research. Indices of diversity or spatial dynamics potentially provide additional information using data from ADAS plots.

8 EVALUATION OF POTENTIAL CONTROL DATA

8.1 AIM AND SCOPE OF THE REVIEW

The aim is to investigate the potential to compare botanical quality and change of agri-environment scheme data with other sources. The two main issues are 1) comparing vegetation condition against external standards and 2) comparing trends in AE schemes with those in the wider countryside. This part of the review looks at potential data sources and considers their application as controls to agri-environment scheme data. It raises issues that need to be considered when establishing controls and discusses some issues relating to statistical procedures and formal tests of difference.

8.2 REVIEW TABLE

Table 8.1 contains references to different data sources, groups them by habitat, characterises them in terms of field method, quadrat size, indicators, analysis, comparability to AE data and other data.

8.3 OVERVIEW OF TABLE

8.3.1 Control Data

Control data are comparable data collected outside a scheme, and are required to answer two types of questions:

- Are there differences in character of vegetation on land entered into the scheme compared with land not entered?
- Are changes in vegetation within the scheme different to those taking place outside the scheme?

The first question relates to selection of land, the second to the management. The interpretation of the comparisons depends upon the objectives of the scheme, and even the individual site; thus, the objective of targeting and maintaining high quality sites is achieved if the vegetation is of desirable character when entered and remains that way. By contrast, a site with the objective of improvement may have a typical vegetation character when entered, but the vegetation increases in conservation quality more than comparable land outside the scheme. Ideally, then, vegetation data are required at the start of the agreements and some time into the agreements, both within and outwith agreement land.

Starting points should be characterised by locating them within the range of floristic variation across a biotope at an appropriate spatial scale (Smart 2000). This range of variation should include intact ‘good quality’ examples as well as communities in a less pristine condition. This can be done using systems such as the CVS and NVC; the former has been used more widely. This approach has been used to calibrate AE scheme samples against independent samples of known quality (Critchley *et al* 1999a; Fowbert & Critchley 2000).

Change data can be analysed using change in CVS or NVC classes, or by direct gradient analysis techniques (Jongman *et al.* 1995; Smart 2000). However, a simpler approach is to summarise this variation using indicator scores, notably suited species and Ellenberg indicators (see Section 7). These indicators provide information about the position of a community along a gradient of change that is both related to management objectives and comparable with other vegetation stands.

There are methodological considerations to take into account in comparing samples with control data. For example, differences in quadrat/plot size can be compensated for to some extent, although it might not be possible to make quantitative comparisons at different spatial scales. Species richness is particularly affected by scale, but other variables such as suited species scores can be as well (Critchley *et al* 1999a). There may be a need to account for the statistical design of site and quadrat selection. The quality (rigour of data collection and validation) of the datasets should also be considered.

8.3.1.1 Establishment of control sample points

Control sampling positions can be established at the time of the AE scheme monitoring, thus ensuring comparability of data in terms of survey methods and quality control. However, this can be problematical for a number of reasons (Critchley 1997). The uptake of a particular type of land into agreement may be so high that non-agreement land becomes a scarce commodity. There is often a fundamental difference between agreement land and non-agreement land in an AE scheme. For example, in the Pennine Dales ESA, most non-agreement land was intensively managed grassland situated at lower altitudes in the ESA, whilst the unimproved hay meadows located further up the valleys, which were of greater wildlife conservation value, were more likely to be entered into ESA agreement. As ESA boundaries normally encompass all land of a certain type that exists in the area, comparable non-agreement land outside an ESA is seldom available for sampling. A further problem common to all AE schemes is that any non-agreement land sampled may be subsequently entered into agreement.

In a number of ESAs, including Breckland, West Penwith and North Peak, livestock were re-introduced to lowland heaths as a result of the land being entered into scheme agreement. This enabled comparisons to be made between fenced plots (simulating the effects of the lack of stock in the absence of ESA management) and unfenced plots (agreement land) (ADAS 1997b). Also in Breckland ESA, conservation headlands were compared with normally cropped headlands on the same farm (Hodkinson *et al.* 1997). In Scottish ESAs, the problem is being addressed by comparing trends between agreement land, land in the whole ESA, and national trends (Cummins *et al.* 1997).

8.3.1.2 Countryside Survey (CS)

Countryside Survey involves the repeated survey of vegetation, land cover and landscape structure of the whole of GB using fixed locations selected at random. It therefore has the potential to be a very powerful set of control data for a wide variety of land management programmes, including AE schemes.

The CS sample design is based on a series of stratified, randomly selected 1km squares. Stratification of sample squares was based on the ITE land classification, taking into account topographic, climatic and geological attributes (Bunce *et al.*

1996). Vegetation plots are arranged within the squares again on a random basis, targeting areas of land, field boundaries and other features, and are relocated at each survey. Data from each plot at each time (1978, 1990 and 1998, with an increase in plot number at each survey) have been classified into CVS classes. Vegetation change is reported by individual country (England, Wales and Scotland) as well as by aggregations of land classes into environmental zones (Firbank *et al.* 2002 in press), Broad Habitat, plot type and major vegetation type (defined as aggregate classes within the CVS). .

Vegetation data are reported for a number of indicators, including Ellenberg scores, CSR strategies, the mean number of species present per plot, the mean species number per plot type, per landscape type, changes in cover of individual species, changes in habitat indicator species and changes in NVC indicator species. Indicators of habitat quality for butterflies and lowland farmland birds are also analysed.

The overlap between Countryside Survey squares and land under agreement in Agri-environment schemes is currently being examined as part of a contract for DEFRA; interim results suggest that it is low. The degree of overlap would be expected to increase substantially under a high take-up entry level AE scheme.

Countryside Survey data are invaluable as time series data representative of the wider countryside. They have been collected using repeatable, carefully designed methods, subjected to quality controls, and uses stratified random sampling. A range of indicators has been used to analyse the data that could be easily calculated for Agri-environment scheme data. There are few data available elsewhere on poorer quality habitat but as CS samples the wider countryside randomly it also contains habitat in less favourable condition. It is not useful as a comparison to all habitats; rarer habitats are unlikely to have been sampled using this method. There was an additional survey (the Key Habitats survey) which used the same methods and some of the same squares but concentrated on five key habitats (Lowland heath, Calcareous grassland, Coastal, Upland, and Waterside) and sampled additional squares. Species have been allocated to habitat indicator groups and species indicator groups. However, this survey has not been repeated so there are only data from 1993.

An example of the use of CS as a control data set comes from the CSS monitoring programme, designed to assess the quality of the land under Countryside Stewardship Scheme agreements and established a baseline for future monitoring (Carey *et al.* 2001a; Carey *et al.* 2001b). The survey used Countryside Survey (CS) methods. Land under agreement was compared with the wider countryside using CS data. The vegetation from each quadrat was categorised in terms of the CVS and NVC. The quality of the habitat was also assessed by mapping Broad and Priority habitats according to field keys to estimate the proportion of land that came into each category. The distribution of CVS classes and Broad Habitat classes were compared with the results from CS2000, showing that vegetation within the scheme was typically richer in infertile grassland than outside. In the absence of baseline data, however, it was not clear whether these differences were due to selection or management; a follow-up survey timed to coincide with the next Countryside Survey (potentially in 2006) will be needed to demonstrate any benefits of management within the Scheme.

8.3.1.3 EN data for monitoring grassland BAP

Currently, a joint English Nature/DEFRA project (AE08) is setting up a national monitoring network of 500 BAP non-designated grassland sites, stratified by agri-environment agreement status (half under agreement). The sample has been drawn from EN Grassland Inventory sites, i.e. unimproved grassland (see 8.3.5.1 below). This will in future provide a comparison between agreement and non-agreement sites.

8.3.1.4 Other sources

Monitoring results from AE schemes can also be compared with those from other independent studies. In the ASPS, the vegetation established under ASPS management options was compared with that from previous experiments and surveys where similar management techniques were used (Critchley *et al.* 2001). Species lists and quadrat data collected from any given habitat have the potential to be used as control data for comparing with that from AE monitoring schemes. Issues such as sampling design and methodology should be taken into account. In particular, the representativeness of the data should also be considered, as many habitat surveys only encompass a small number of sites or a restricted geographic region, reducing the validity of the comparison. Some upland grassland communities represent degraded examples of other communities (such as heathland), and so a number of communities might need to be compared together.

8.3.2 DISCUSSION

Control data are vital to distinguish between change within agreement land and within land beyond, and are vital for the evaluation of any AE scheme. There are two fundamental approaches. The first is to include controls explicitly within the design, thus ensuring that the methods are comparable. The second is to use existing data; CS is appropriate for large scale evaluations of rather frequent vegetation types, but scarcer vegetation is little represented. Therefore there is value is considering more specialised habitat surveys. In both cases, it is easier to ensure comparability of methodology than it is to ensure that like habitats are being compared with like.

The introduction of an entry level AE scheme poses special problems for acquiring and interpreting control data, given its anticipated high take up. Land could be kept outside the scheme to act as controls (in which case, how would changes on such land be interpreted in the future?) or, alternatively, land within the scheme could be considered as the baseline control level for higher tiers.

9 REVIEW OF CONDITION ASSESSMENT

9.1 AIM OF REVIEW

There has been a growing interest, primarily among the statutory conservation agencies, in developing and testing rapid methods of site assessment. Given resource constraints in terms of time and money, and the number of sites to be monitored, there is a need for assessment methods which are quick, simple, repeatable, do not require high levels of expertise and provide effective assessment of site condition. These methods are still in development and few data are yet available to assess their performance. This review provides an overview and discussion of rapid assessment methodologies and begins to explore their applicability to agri-environment schemes.

9.2 CONDITION MONITORING METHODOLOGIES

The statutory nature conservation agencies (English Nature, Countryside Council for Wales, Environment and Heritage Service (Northern Ireland) and Scottish Natural Heritage), co-ordinated through JNCC, are developing a common approach to assessing the condition of Sites (Areas) of Special Scientific Interest using rapid monitoring methods. The production of these common approaches has been delayed and the draft versions, which were originally expected March 2002, are now expected before the end of 2002. Progress on production of methodologies differs between habitats. A methodology for assessment of woodlands has been produced, which represents a common standard for all agencies (Kirby *et al.* 2001). This is being used as the basis for further training of agency staff and is linked to a validation programme over the next two years. For other habitats, however, monitoring methodologies currently differ in some respect between agencies. The methodologies reviewed here are therefore in different stages of development, and some (e.g. for assessment of ponds) are not yet available for comment.

Prior to the work co-ordinated by JNCC on common standards methods, English Nature had developed and published protocols for rapid condition assessment of most habitats (English Nature 1999).

9.3 A FRAMEWORK FOR MONITORING

The overall framework for monitoring sites has been agreed between agencies and is outlined in *A statement on Common Standards Monitoring* (JNCC 1998) This framework involves firstly identifying the feature of conservation interest in a site. *Conservation objectives* are decided, to determine the definition of ‘favourable condition’ for a feature. *Attributes* are then determined which indicate the condition of the feature. Finally, *target* ranges for these attributes are set that represent favourable condition for the feature. The condition of the feature can be monitored by examining the values of the attributes, with reference to their target ranges.

- Features

These are the interest features for which the site has been notified or designated and may consist of habitats, species or geological features. For example, for a chalk grassland site, the CG2 vegetation and a population of early spider orchids may both be features of the site.

- Conservation objectives

Conservation objectives are set for each feature to define what constitutes favourable condition for that feature, by describing broad targets that must be met. Objectives are expressed in terms of attributes and targets. For assessment of designated sites, the objectives are used in two ways: 1) as the basis for monitoring - to define condition status; and 2) as part of the process to evaluate proposed management changes or other impacts to the site - to determine whether these are acceptable or not in terms of nature conservation.

- Attributes

An attribute is described by the JNCC Common Standards framework as “a characteristic of a habitat, biotope, community or population of a species that most economically provides an indication of the condition of the interest feature to which it applies”. It is a measurable characteristic of the vegetation or of the site as a whole. Attributes for habitats may include the area or extent of that site, species composition and structure. They may also include essential processes that determine habitat quality. For example the draft *Conservation objectives for maritime cliffs, sand dunes and vegetated shingle* includes coastal processes, and hydrological regime among a number of selected attributes for these habitats.

- Targets

A target is a range of values for a particular attribute, which represents favourable condition for the interest feature. The target encompasses the range of acceptable fluctuation of the attribute while still considering the interest feature to be in favourable condition. Targets should describe the state of a particular feature and not the management systems or operation leading to that state. Kirby *et al.* (2001) note that targets should be capable of being assessed consistently in a relatively brief visit to the site (for a 10-20 ha site - 2 - 5 hours). As far as possible these should have a wide time window for recording and should not rely too heavily on specialist experience.

9.4 SCOPE OF THE REVIEW

The following methodologies have been considered in this review. Examples of attributes, targets and a brief description of the sampling methodology are included for most methods in the accompanying table (Table 9.1):

- Woodlands - all agencies – Kirby *et al.* (2001) *Objective setting and condition monitoring within woodland Sites of Special Scientific Interest*

- Upland habitats - English Nature – Jerram *et al.* (2001) In: Backsall *et al The upland management handbook - Information note 1- assessing vegetation condition in the English uplands*

- Uplands - DEFRA Rural Development Service and the National Assembly for Wales Agriculture Department – Glaves *et al.* (2001) - *The moorland appraisal pilot project (MAPP) (draft)*

- Uplands – Scottish Natural Heritage – MacDonald (2002). *Draft UK Guidance on Conservation Objectives for Monitoring Designated Sites: Dry heath (upland).* Uplands and Peatlands Group Advisory Services

- Lowland grassland - English Nature - Robertson & Jefferson (2000) *Monitoring the condition of lowland grassland SSSIs - Part 1 English Nature's rapid assessment method*. English Nature research reports Number 315.

- Lowland grassland – English Nature - Robertson *et al.* (2000) *Monitoring the condition of lowland grassland SSSIs - Part II A test of the rapid assessment approach*. English Nature research reports Number 315

- Lowland grassland – English Nature – Robertson *et al.* (2002) *Monitoring grassland Biodiversity Action Plan Targets: condition and restoration assessment methodologies for non-statutory grasslands.*

- Lowland grassland – MAFF – Kirkham *et al.* (2001) *Development of sward-based guidelines for grassland management in ESAs and Countryside Stewardship.*

- Lowland heath - English Nature - Alonso (2001) *Common standards for monitoring lowland heathland*

- Arable habitats – MAFF – Firbank *et al.* 2001 *Development and validation of a methodology for the condition assessment of extensively managed arable habitats.*

- Restoration monitoring (many habitats) - Burch *et al.* (1999) *Habitat restoration monitoring. Development of monitoring methodologies within the Ouse and Alde trial areas*. Peterborough. English Nature Research Reports, No 321.

- Restoration monitoring (many habitats) - Mitchley *et al.* (2000) *Habitat restoration monitoring handbook.* Peterborough. English Nature Research Reports, No 378

- Monitoring methodologies (many habitats) - Countryside Council for Wales - Hurford & Perry (2001) *Habitat monitoring for conservation management and reporting. 1. Case studies.*

- Monitoring methodologies (many habitats) - Countryside Council for Wales - Brown (2001) *Habitat monitoring for conservation management and reporting. 3. Technical guide.*

- Agri-environmental scheme monitoring - Tir Gofal monitoring - CCW - ADAS (2002) *Performance indicators for Tir Gofal habitat management prescriptions. Draft 5*

- Agri-environmental scheme monitoring - Environment and Heritage Service (Northern Ireland) - Corbett, P. (2002) - personal communication

9.5 REVIEW TABLE

The new methods reviewed in this document are summarised in Table 9.1. Methods are described giving details of authorship, habitats covered, attributes assessed, management targets, survey method used and any other relevant information.

9.6 ANALYSIS OF METHODOLOGIES

9.6.1 Choice of attributes and targets

A number of attributes are common to many of the habitat types. For example, extent of the interest feature is included in all SSSI condition assessments, while components of vegetation composition (e.g. positive and negative indicator species) and structure (e.g. sward height, bare ground) are included in many habitat monitoring methods (e.g. Burch *et al.* (1999); Robertson & Jefferson (2000); Alonso (2001)). Other attributes may be very habitat specific. For example ponds and ditch restoration include bank profile as an important attribute, while woodlands include targets for ride structure and dead wood under the attribute 'natural processes and structural development' (Kirby *et al.* 2001).

In grasslands, field methods for assessing sward attributes have been developed to some extent within existing methodologies, e.g. Robertson & Jefferson (2000); Burch *et al* (1999). In addition to this work, Kirkham *et al* (2001) developed sward-based guidelines for assessment of grasslands in agri-environment schemes. Their recommendations included the use of the HFRO sward stick rather than the drop disc method for measurement of sward height. They also found that visual estimates of sward height and herb, weed and tussock cover were feasible at the field scale. However, they concluded that visual estimates of bare ground at the field scale were more difficult, requiring a more systematic approach. They also identified the need for more reliable methods for measuring litter cover and for assessing sward heterogeneity.

Where target species are used as performance indicators of good condition these are typically based on NVC communities, although species used are generally limited to those that can be easily recognised, to minimise recorder error. While this is tenable for SSSIs, this approach is less suitable for agri-environment re-establishment/restoration sites where the starting point may bear little relation to the desired community endpoint and vegetation may develop in an unpredictable way. Rigid NVC-type targets do not allow for this and may result in failing a site which in fact is developing into a community of considerable conservation value. Burch *et al*. (1999) provide guidance lists for recorders of target species based on NVC constants and other species known to be characteristic of restoration swards.

English Nature has begun to define "restorability indicators" for lowland grassland (Robertson *et al.* 2002). Restorability indicators include species that may be useful indicators of favourable substrate conditions for re-establishment, such as lower nutrient levels or a suitable hydrological regime, but may not be constants of the target grassland community and, in some cases, may be a potential problem later in the restoration (e.g. *Deschampsia flexuosa* in acid grasslands). The current list is still in preparation and no testing has been carried out so far, but it is expected to be use in conjunction with the positive indicators already identified for established grasslands (Robertson & Jefferson 2000). Examples of the proposed species are given in Table 5.2 below.

Wet grassland	**Neutral grassland***
Cirsium palustre *Pulicaria dysenterica* *Juncus conglomeratus* *Carex riparia*	*Veronica chamaedrys* *Prunella vulgaris* *Crepis capillaris* *Potentilla reptans*
Acid grassland*	**Calcareous grassland***
Deschampsia flexuosa *Luzula multiflora* *Hypochoeris radicata* *Potentilla anglica*	*Brachypodium sylvaticum* *Daucus carota* *Galium mollugo* *Medicago lupulina*

Table 5.2: Examples of "Indicators of potential for re-establishment"

* NB Moist and dry grasslands have been combined here to simplify presentation

The Moorland Appraisal Pilot Project (draft report (Glaves, *et al.* 2001)) is in the process of testing a number of attributes which could be indicative of grazing pressure on moorland vegetation types and determining thresholds for those which are indicative of over-grazing. The fifteen attributes currently being tested include many related to vegetation cover and structure, as well as attributes such as bare ground and faecal events. The full list is given in the accompanying table.

English Nature has also produced interim result of a monitoring methodology for non-statutory lowland grassland sites (Robertson *et al.* 2000). This approach utilises the same attributes set out in Robertson & Jefferson (2000), but adapts target thresholds to account for the generally poorer quality of these sites. They conclude that appropriate thresholds for attributes defining favourable condition should be the subject of further discussion among partners from the grassland Habitat Action Plan group (Robertson *et al.* 2002). They also conclude that field testing and validation of rapid assessment of restoration (re-establishment) potential is required (Robertson *et al* 2002).

9.6.2 Sampling methodology

The majority of condition monitoring methodologies (e.g. Mitchley *et al.* 2000; Robertson & Jefferson 2000; Kirby *et al*. 2001) utilise some form of structured walk in order to assess condition. In most cases, a W-shaped or other walk is suggested with a number of pre-determined sampling positions (typically 10 or 20) evenly spaced along the walk. However, CCW are intending to use random spacing for Tir Gofal monitoring (K. Austin in litt. to RDS). In Northern Ireland, the Environment and Heritage Service are utilising GPS to accurately record and thus relocate these points for subsequent recording (Corbett 2002 pers. comm.). A similar approach is suggested for the trial of Tir Gofal performance indicators in Wales (ADAS 2001b).

At each of the sampling points attributes are either assessed against the given targets or the attributes are measured/estimated, although in most cases it is also expected that the condition should also be assessed between sampling positions. Some methodologies detail the size of area to be assessed at each sampling position. For woodland a 50 x 50 m square is suggested (Kirby *et al*. 2001) , for lowland grassland a 3 - 4 m^2 in front or around the recorder (Robertson & Jefferson 2000). For re-establishment/restoration sites, Mitchley *et al*. (2000) suggest the 1 m radius semi-circle directly in front of the recorder.

Mitchley *et al*. (2000) also differentiate between “straightforward” and “complex” restoration habitats in terms of sampling methodology. The former includes habitats such as woodlands, hedgerows, field margins and coastal grazing marsh, where it is felt that the recorder can make an overall assessment of the site during the structured walk without the need for individual sampling positions. The latter group includes habitats such as grasslands and heathlands where it is felt that more detailed examination of the vegetation at sampling positions is required to identify critical species. Even in these habitats, not all attributes are assessed at the sampling position level and the recording form indicates those, such as litter cover, which are to be assessed for the site as a whole and those, such as positive and negative indicator species, which are recorded at each sampling position.

In contrast to the above methodologies, more rigorous sampling approaches have also been suggested, especially for more extensive habitats such as moorland. These include a SNH proposal to sample moorland using random points (28 to detect a 10% ‘failure’ rate) within each interest feature (MacDonald 2002). CCW suggest a gridded approach to sampling sites, which is termed a “mapping” approach (Brown 2001). It is argued that structured walks, as detailed above, sample far too little of the site in question and carry the significant risk of coming to false conclusions about site condition. The mapping approach utilises a grid of evenly spaced points, close enough together to consider that the whole feature has been sampled. Although this sounds daunting, Brown (2001) points out that a survey of the whole site may not be necessary. For example if a lower limit for a feature sets a target of at least 80% of points to pass and after visiting 30% of points all have failed, then it can be concluded that the feature is in unfavourable condition. This, however, would generate relatively little data on the site, for example for determining subsequent change. An alternative “selective” approach is also discussed which relies on expert judgement to select diagnostic areas of the site to be sampled in order to determine feature condition. This may be, for example, the most damaged part of the site or the least damaged, but such an approach is only suitable with extensive site knowledge.

In the mapping approach, the initial grid layout is calculated according to the time available, and a GPS system used to locate points. Recorders are expected to check habitat variation between sampling points once in the field and adjust spacing if necessary. The mapping approach “depends on making sure that the grid scale is finer than the scale of habitat variation between points in the field” (Brown 2001). Finer scale habitat variation is dealt with by ensuring that the sampling position is of an adequate size. In general, a circular plot within 1 m of the sampling point is suggested. Assessment is made both through formal recording at the sample points and, like other methodologies, informal observations in between.

Each sample point is assessed and classified in terms of habitat type according to a number of site-specific habitat definitions, rather than assessing a number of attributes against their targets at each point. Thus favourable condition is determined for each feature on a site-specific basis, with lower and sometimes upper limits defined according to vegetation type e.g.:

> "Lower limit - the coastal and maritime heaths comprise a vegetation where: >60% of the heath is open heath which includes >20% open, species-rich heath and where *Pteridium* or scrub covers <20% of the section"

(Source: Hurford & Perry 2001)

Thus if more than the 60% of sampling positions conform to this description, then the feature can be considered in favourable condition.

It must be noted that while CCW's argument may be valid and 10-20 sampling positions may not represent a full assessment of site condition in isolation, most methodologies also require the recorder to take into account the site as a whole as they complete their structured walk. Thus general site observation may also be taken into account in assessing feature condition and equally it is likely that sample positions that are considered very unrepresentative of the site as a whole may be either relocated or that information not utilised. In fact, this requirement of the recorder to consider overall site condition can be considered a significant advantage of such methodologies. It ensures that maximum use is made of the field visit and equally draws on the knowledge of the recorder, who on visiting many such sites would be expected to develop some expertise in assessing overall site condition. However a number of authors have suggested that there is a limit to the area that can be covered by a structured walk (e.g. Robertson & Jefferson 2000) suggest a maximum area for grassland of 15-16 ha).

9.7 DISCUSSION

9.7.1 Site specific vs. generic attribute and targets

A significant issue for discussion during the development of these methodologies has been the wisdom of adopting a generic or site-specific approach to developing attributes and targets.

For example, English Nature's current methodology for Robertson & Jefferson (2000) adopts both generic attributes and targets for each grassland type. Three broad attributes: extent, sward composition and sward structure are applied to all grassland types, with the latter two divided into several components for each type (typically defined by NVC categories) with detailed targets in terms of the acceptable range for particular attributes or maximum / minimum thresholds of species occurrence. In the Upland Management Handbook, Backsall, *et al*. (2001) also prescribe carefully worded but generic attributes and targets for each upland habitat type.

In contrast, Kirby *et al*. (2001) have adopted a methodology for woodlands which utilises a limited number of broad attributes which are then assessed using site-specific targets, with several typically associated with each attribute. The restoration monitoring methodology of Burch *et al.* (1999) and Mitchley *et al*. (2000) also adopt a site-specific approach with opportunities for both attributes and targets to be adjusted to accommodate individual site conditions. Site specificity enables factors such as past site history, the location of the site (particularly in terms of colonisation sources), restoration method and particular problem species to be taken into account (Mitchley *et al*. 2000).

This debate has yet to be resolved. Nonetheless there is still the prospect of a common model being adopted which, like that proposed for woodlands, uses generic attributes for each habitat to be assessed against site-specific targets. This ensures some consistency between sites and agencies while allowing for regional variation and local distinctiveness. JNCC support a limited degree of flexibility to account for geographical or other variation for designated sites. There is a stronger case for generic targets for a national monitoring programme especially when sites may not have site-specific objectives. There may not be a single answer to this issue since it depends upon the use to which the data is to be put.

9.7.2 Categorising site condition

Common standards monitoring requires that all features be assessed according to the JNCC condition categories as set out in JNCC (1998):

Favourable - maintained
Favourable – recovered
Favourable - declining
Unfavourable - recovering
Unfavourable - no change
Unfavourable declining
Partially destroyed
Destroyed

These condition categories provide a UK wide standard against which habitat, species and geological features can be assessed and related to BAP targets, and used to fulfil European and International reporting requirements.

Scoring systems have been adopted in some methodologies. For example, Burch *et al.* (1999) and Mitchley *et al*. (2000) adopt a scoring system, with targets, which are met scoring 2, those almost met - 1 and those not met - 0. The value of this scoring system is not discussed however, with no indication of the level of score required to determine favourable site condition, or degrees of failure. There is also a grey area in deciding which targets are almost met and thus deserve a score of 1.

Jerram *et al*. (2001) also adopt a weighted scoring system in their methodology for assessing upland condition. In this approach the scoring system is used to distinguish between degrees of unfavourable condition, thus enabling managers to direct scarce resources to those features / sites most likely to yield results. A score is given for each attribute failed, with additional weighting given to those attributes considered to be of particular importance in determining feature condition. In these cases, scores are sub-divided with more points awarded to poorer examples of a particular condition.

There is a danger in using a scoring system of adopting a pseudo-quantitative veneer to what is essentially a qualitative form of assessment. Unless there is a strong justification for scoring and thus ordering sites or features, as suggested by Jerram *et al*. (2001), then scoring as a record of condition assessment should be avoided. However, condition categories provide a more effective and transparent method of assessment.

9.7.3 Evaluation of populations of individual target species

Sites in the AE schemes with populations of rare species are a special case. While habitat condition may be critical for species survival, it may also be desirable to provide some assessment of individual species success. To some extent condition assessment can be used as a surrogate for species population assessment e.g. by monitoring habitat components such as vegetation structure and the presence of food plants. A study by Firbank *et al.* (2001) explored the validity of habitat assessment as a method of forecasting species occurrence within the Pilot Arable Stewardship Scheme. While habitat assessment provided a useful forecast for two invertebrate groups (Carabids and Heteroptera) little correlation was found for both birds and rare arable plants. Thus, habitat condition assessment in isolation must be used with caution as a method for monitoring individual rare species populations. Methodologies do exist with Common Standards Monitoring e.g. counting numbers of individuals, reproductive success and survival, but further analysis of this issue is beyond the remit of the current study.

9.8 EVALUATION

In order to evaluate these methodologies a number of predetermined criteria were set before commencing on this review, these are discussed individually below:

9.8.1 Time taken per site

A critical factor in evaluating a rapid method of assessment must be the time taken per site A number of authors provide some indication of the likely time needed for carrying out the methodology. For example, for woodland Kirby *et al*. (2001) suggest 2-3 hours for a straightforward site up to about 20 ha and for larger or more complicated sites, a whole day; for lowland grassland Robertson and Jefferson (2000) suggest 30-45 minutes if no structured walk is done and an additional 30-60 minutes to be allowed for the structured walk; for upland habitats Jerram *et al*. (2001) suggest half a day to one day; restoration sites (Burch *et al.* 1999) - typically one hour or less.

The rapidity of many of these methods and their comparative simplicity in the field belies the expertise required in setting them up. In terms of time and expertise this is very much a ‘front-loaded methodology’, with large inputs required at the outset, in devising the methodology, determining suitable attributes, typically on a generic basis for a particular habitat and then defining suitable targets. Once this process is completed, however, the methodology has the potential to provide a simple, repeatable and rapid method of monitoring sites.

9.8.2 Qualitative vs. quantitative data

Many methodologies include the collection of some quantitative data, such as the frequency of indicator species at a number of sampling positions. However, assessment is largely based on a qualitative judgement of site condition, albeit one which is made within certain pre-determined criteria (attribute and targets). Only the CCW and MAPP mapping methodologies provide a more quantitative approach, given the number of sampling points recorded.

9.8.3 Amenability to statistical analysis

In general most of these methods are unsuitable for statistical analysis. Where sample positions are used to collect information, these are not randomly selected and the number recorded too small to be statistically valid. In most cases an element of subjectivity is included in the assessment and observations made between sample positions are taken into consideration in determining feature condition. Both the CCW mapping approach utilising a large grid of points and the SNH random sampling method provide information potentially amenable to statistical analysis.

9.8.4 Provision of management information

Most of the methods examined provide a rapid assessment of management needs which is determined in the field at the time of recording. Information such as the over-abundance of negative indicator species, inappropriate sward height etc. can be used to trigger changes in management prescriptions for the site. Rapid assessment provides the opportunity to monitor these changes and ensure that the management is appropriate for site objectives. The CCW mapping approach however, may only answer the question - is the site in good condition? – if as is suggested recording can cease once this question has been answered. Thus little or no information may be gathered on the particular management needs of the site. In contrast, Jerram *et al*. (2001) methodology for uplands provide the opportunity to score 'unfavourableness' and thus to prioritise management needs across a number of sites.

9.8.5 Level of expertise required

All methodologies require some botanical expertise in recording key indicator species. However the list is typically limited and it would be expected that recorders would soon become familiar with the identification of these critical species. In general, attributes and species that require specialist identification skills are avoided. Unlike conventional quadrat recording there is no requirement for all species to be identified and recorded, thus avoiding identification problems. In contrast however, these methods typically require some level of subjective recorder judgement of site condition. While this is framed within given criteria for the particular feature, the recorder is expected to make an overall assessment of the site, or in the CCW mapping approach an assessment of each recording point. It would be expected that the recorder would initially bring some level of expertise to such a task and develop this expertise as more sites are visited.

A critical factor in terms of expertise is who will carry out the monitoring work. There is a marked difference between the statutory agencies in this respect and thus a difference in the finer detail of their methodologies. At one extreme, English Nature proposes to use conservation officers to carry out condition monitoring of at least a proportion of SSSIs, thus restricting the choice of indicator species to those which can be easily and reliably identified. In contrast, the Environment and Heritage Service (Northern Ireland) will carry out all monitoring using a dedicated recording and monitoring team. This allows more sensitive and hard-to-identify indicators to be utilised and more complexity added to the methodology where necessary.

9.8.6 Scientific validity

Validation of these methodologies using quadrat recording is essential to ensure that they are assessing condition effectively and picking up critical components of the vegetation that would be detected using more rigorous methods. In many cases it will only be through repeated condition monitoring and associated validation that the choice of attributes and target levels can be properly assessed and adjustments made for future recording. To date, few of the methodologies have undergone rigorous validation testing, although work is in progress to develop a network of validated sites to test the methodologies in the future. Only English Nature's lowland grassland methodology has undergone a more rigorous validation Robertson *et al*. (2000), with three grassland types tested on a total of 15 sites. Overall this demonstrated the rapid assessment method to be robust between different recorders and allowed the relationship between selected indicator species and site condition to be examined, leading to further refinements of the methodology. Testing has also been carried out of the woodland methodology although the results are not yet published. Validation of some sites in the restoration monitoring project Burch *et al.* (1999) showed approximately 50% agreement between quadrat and rapid assessment methods in determining attribute condition. Where anomalies were identified, changes to the monitoring methodology or targets set were suggested for future monitoring.

9.8.7 Ability to cope with site heterogeneity

Site heterogeneity can be a significant problem in setting out an appropriate monitoring methodology. For example, the NVC-driven approach utilised by Robertson & Jefferson (2000) may be difficult to apply in vegetation that does not conform to any particular NVC community. In many cases habitat mosaics or transitions complicate the picture and may require separate recording forms and zoning of the site to provide adequate coverage of the different communities. This adds to the argument for site specificity, where adaptations for heterogeneity can be written into the monitoring scheme from the outset. For example, where colonisation from an adjacent source is an issue, a site may be zoned into margin and core for some attributes to take account of this. The CCW mapping approach is particularly well suited to coping with habitat mosaics, as for example; a target percentage can be set to allow for a mosaic of two or more habitat types.

9.9 ISSUES FOR FURTHER DISCUSSION

9.9.1 Comparing condition assessment with conventional quadrat recording

While validation is essential to assess condition monitoring against conventional quadrat recording, another important question is whether condition assessment provides additional information that a more rigorous quadrat method does not. Clearly, in many ways the type of information picked up in a condition monitoring approach would equally be picked up via quadrats e.g. frequency and broad cover estimates of bare ground and individual species. What quadrat recording does not typically allow for is the scope for the recorder to make an overall assessment in the field. Sometimes a visual assessment of what is happening in the field as whole, framed within the criteria set out within the attributes/targets, can be as useful as detailed species information provided within quadrats.

Another important distinction between quadrat and condition monitoring is the point at which an assessment of site condition is made. In conventional quadrat methods, data is collected in the field and then analysed later to provide an assessment of sward development. In condition monitoring, an assessment of feature condition is typically made immediately in the field, although some additional information may need to be obtained after the visit. This offers the scope for some further assessment of management needs to be made, if condition is judged unfavourable, at the time of recording, as well as the considerable saving in terms of data entry and analysis.

Quadrat data could be used to assess against JNCC condition categories if clear objectives, attributes and targets are set. However there is a danger that this method may result in collecting far more information than is necessary to answer the question. In all monitoring projects, the amount of data recorded should depend on the question being asked.

In this respect, once condition categories and targets have been set in relation to site or scheme objectives, the RCA data will answer the questions set. However the RCA cannot easily be reassessed against changing criteria or objectives. This is a major strength of quadrat data, which does provide this kind of objective flexibility to adapt to changing priorities and objectives and to address new questions as they may arise.

9.9.2 How often should sites be monitored?

The Common Standards Monitoring Cycle states that all features on all sites should be monitored within consecutive six-year periods. However several authors advocate more frequent visits than this. Robertson & Jefferson (2000) suggest that visiting frequency should be determined on a site-specific basis - “as often as necessary to secure favourable condition”. CCW’s Tir Gofal methodology suggests monitoring at the commencement of the agreement and then in years 4/5 and again in years 9/10 at the end of the ten-year term. The restoration monitoring methodology of Burch *et al.* (1999) and Mitchley *et al*. (2000) adopts a similar pattern although an additional recording period is included in years 2/3. This is perhaps unnecessary and also unlikely given resource restraints. An argument for this however would be the ability to pick up management problems early in the restoration, rather than waiting until half way through the agreement.

10 EXISTING AND POTENTIAL ADDITIONAL ENVIRONMENTAL DATA

10.1 AIM AND SCOPE

The aim of the review is to evaluate the importance of environmental data additional to botanical monitoring, with particular reference to data collected within agri-environment schemes of England and other UK countries. Such data include field level information on soil, topography, weather, management practices, ditch physical and chemical properties, farm socio-economic characteristics and data on atmospheric deposition of pollutants.

10.2 OVERVIEW

10.2.1 Soil

Vegetation character is intimately dependent upon soil pH, drainage, nutrient status, organic matter and structure. Soil data can therefore be used to interpret present patterns of vegetation, and also to identify potential constraints against achieving some desirable vegetation condition. Soil data have been collected as part of many AE monitoring programmes.

In English ESAs, soil samples were collected from botanical monitoring sites in grasslands and related vegetation under DEFRA-funded research project BD1429 (Chambers *et al.* 1999; Critchley *et al.* 2002; Critchley *et al.* in press). Soil samples were taken from 16 ESAs during 1995-1997 and analysed for pH, extractable phosphorus (P), potassium (K) and magnesium (Mg), total nitrogen and organic matter, and assessed for texture. Such data are also available from the Arable Stewardship Pilot Scheme (ASPS) (Critchley *et al.* 2001). Soil samples from the Habitat Scheme Saltmarsh Option monitoring sites were analysed for were pH, salinity (exchangeable sodium (Na) %), concentration of the electrolytes potassium (K), Na, calcium (Ca), magnesium (Mg) and chlorine (Cl), and redox potential (ADAS 1998b).

In the Moorland Scheme monitoring programme, soils were sampled (ADAS 1998h) but the data had not been reported on before the monitoring programme was discontinued. No soil sampling has been carried out in the monitoring programmes for the Countryside Stewardship Scheme and the Farm Woodland/Farm Woodland Premium Schemes.

In all six Welsh ESAs, a similar sampling programme to that in English ESAs was carried out during 1997-1999 under project BD1429 (Chambers *et al.* 2000). In addition, soil samples (0-15cm depth) have been taken adjacent to plots at the same time as each botanical survey in the monitoring programme (Table 2.1). Over a 3-4 year period, some significant changes in soil properties were detected, but these were small in magnitude. In Northern Ireland, soil samples have been collected from ESAs as part of the monitoring programme, and in the Republic of Ireland from the Rural Environment Protection Scheme (REPS) (Table 3.1). In the first phase of monitoring of Scottish ESAs, soil type was also recorded.

All of these sampling programmes have the potential to be used as baselines for changes in soil properties. Moreover, soil samples were collected during the Countryside Surveys of 1978 and 2000 and provide a control dataset that shows the changes in soil condition over that period for the wider countryside, using a range of potential indicators currently under development.

Analysis of English and Welsh ESA samples have revealed clear relationships between species composition and sets of soil variables, and relationships were also detected in other AE schemes. Soil data are often important explanatory variables in accounting for variation in vegetation encountered in AE schemes. Particular plant communities will therefore be sensitive to changes in soil properties, especially pH and nutrient status. The raising of soil nutrient status would be likely to have a rapid detrimental effect on most semi-natural vegetation. The response of vegetation will often lag behind changes in soil properties, and so measurement of soil properties might give an early warning of the likely response of the vegetation. However, changes in soil properties are only likely to take place slowly. For example, in the absence of fertiliser N additions, soil pH decreases of c. one pH unit only occur over a period of several decades (Johnston *et al.* 1986). Similarly, soil total P can still be declining 45 years after the last application of fertiliser (Olff *et al.* 1994). Only small changes to soil properties have been detected to date in the monitoring programme for Welsh ESAs. Therefore, soil sampling need not be done frequently.

10.2.2 Physical and chemical properties of ditches

Just as soil properties influence vegetation, so do other parameters (including water width, depth, flow, colour, visibility and conductivity, bank depth and slope, and dyke bottom substrates) influence the vegetation in and at the edges of ditches.

Such data have been collected from appropriate ESAs, i.e. the Broads, Somerset Levels, South Downs and North Kent Marshes (ADAS 1991c; ADAS 1991d; ADAS 1996b; ADAS 1997j). The water conductivity measurements collected in the Broads ESA were used to try to explain changes in vegetation, although changes in conductivity and vegetation did not always correlate. In the North Kent Marshes the conductivity was measured in one year only, therefore changes over time could not be determined.

In the Somerset Levels and South Downs ESAs rhyne/ditch monitoring was carried out on small samples therefore it was difficult to draw firm conclusions. The only trend observed was that of declining water levels in the Somerset Levels, though it was not possible to relate these to species diversity for which there was no evidence of change. In these and the Broads ESAs, the other measured parameters were not formally used in the interpretation of the results, though they might have provided useful background information.

The most useful environmental parameter recorded in ditch surveys was water conductivity. Eutrophic status is linked to conductivity levels and, generally, dyke vegetation quality deteriorates as the conductivity and/or nutrient levels in the water increase. However, brackish communities associated with high conductivity and/or nutrient levels can also be of conservation importance. Other data such as water depth may also provide useful interpretative information but their value should be weighed against cost of collection.

10.2.3 Topography

Slope and aspect were collected as part of the survey for the first stage of the Scottish ESAs and also, along with altitude, in conjunction with the GI/BU data for the English ESAs (ADAS 1997c; ADAS 1997h; ADAS 1997i; ADAS 1997l; ADAS 1998f). In the English ESAs the relationship between the environmental data and BU was determined using stepwise regression. The results varied between ESAs, but with the exception of altitude in Exmoor, altitude, aspect and slope were not, however, powerful predictors of BU. Altitude and topography were noted by surveyors as part of the CSS (Carey *et al.* 2001a).

Topography data are also available from national digital terrain models at several resolutions. While the value of such data in AE monitoring has not been demonstrated, they may be useful to help target site selection for new agreements.

10.2.4 Meteorological data

Weather exerts great influence on plant growth and community dynamics. Meteorological Office temperature and rainfall data have been used to interpret some vegetation changes in some ESAs; thus, in tier 2 of the South Downs ESA, (semi-improved mesotrophic (river valley) grassland) there was a decrease in the W score (species suited to prevailing high moisture content) (ADAS 1996f). This decrease was attributed to the dry weather. Dry weather was also used to explain the decrease in height in tier 1(3) of the South Wessex Downs ESA (ADAS 1997k) (unimproved, calcareous downland). In the Suffolk River Valleys ESA, dry weather inhibited maintenance of high water levels of the wet grasslands, and the W score decreased in the fen meadows (ADAS 1997e).

It has been shown that the weather is an important factor when trying to explain changes in vegetation in the short term, and it is, potentially, even more important in the long term. Weather data is readily available. More importantly, the Environmental Change Network (ECN), the DETR indicators of climate change (DETR, 1999) and the UK Phenology Network provide national control data on the responses of vegetation to weather, and have the potential to help interpolate between CS surveys. The ECN has a network of sites across Britain that regularly record data on a daily/seasonal basis for a range of standard variables, including meteorological ones. The network has been specifically designed for the early detection of environmental trends such as climate change. There are 12 terrestrial sites and the network began in 1992 (Tinker 1994). ECN sites particularly useful for comparison against AE botanical data are those that have historically been managed for agriculture and currently have rough grazing, improved pasture or arable land uses, and vegetation at ECN sites are monitored and reported in ways comparable with CS. This would be especially useful for indicating the effects of severe drought on grassland. In the longer term, the ECN data will also provide an important control data set for the detection of global climate change signals.

The DETR indicators of climate change are only of limited use for comparison with agri-environment scheme botanical monitoring, since the measurements rely on condition of species and timing of events rather than population levels. Similarly data from the Phenological Network cannot readily be related to AE monitoring until relationships between species phenology and population levels and distributions can be established.

10.2.5 Field management practices

Management of land under agreement is the mechanism by which the agreements are assumed to influence vegetation. Therefore, data on the relationships between management and vegetation are essential to ensure the development of agreement prescriptions, and to assess the contribution of management to vegetation change compared with other factors, such as weather.

Within the English ESAs, information on the management history of many of the grassland and heathland monitoring sites (see Table 2.1) was obtained by questionnaire from agreement holders. The information covered all aspects of management and included cropping, grazing regime, cutting regime, fertiliser applications and other chemical treatments. Data on the history of drainage, re-seeding and liming practices were also collected. Quantitative analyses to relate management data to vegetation condition or change were not generally done (apart from agreement status or management option), because of the difficulty in standardising management data, but management data were useful for interpreting the potential causes of vegetation change.

In the South Downs ESA, in the permanent grassland option, the sites were classified into endgroups. In the ‘well-grazed unimproved chalk grassland endgroup’, calcicoles decreased in the sward, consistent with the reported reduction in grazing pressure and a shift from sheep to cattle grazing. In the ‘under-grazed unimproved chalk grassland’ endgroup, species suited to high nutrient availability was seen to decrease. This was related to the management data, which showed that half of the fields concerned had received nutrient enrichment prior to but not after entry into the scheme (ADAS 1996f). In the Pennines Dales ESA, reductions of Nu scores corresponded with a reduction of fertiliser inputs (ADAS 1996d).

In the Suffolk River Valleys ESA, an increase in G score (species suited to grazing) was detected in two endgroups, ‘semi-improved dry acid grassland’ and ‘grass/heath scrub developing on former arable land’(ADAS 1997e). The introduction of grazing by livestock at the start of the ESA probably contributed to the increases in G scores observed. Summer drought, in acting as a disturbance and favouring certain annual species which are also suited to heavy grazing, may have contributed to the high G scores, which highlights how management might interact with weather. Relatively high G scores in the first year were attributed to rabbit grazing.

In the Pennine Dales ESA, an attempt was made to formalise the relationship between management and vegetation communities (Askew 1994), although the management data had to be standardised into broad categories.

Management data may be less valuable than might be expected, as the data are taken from agreement holder records rather than from independent observations, and so may be inaccurate or incomplete. In spite of this, the information can provide useful contextual and background information when interpreting the results of the monitoring, even where analysis of the data is not possible. It is possible that these links could be more formalised in order to maximise the usefulness of the collected data. Moreover, as farms are required to maintain better management records as part of quality assurance schemes and other parts of their business, it may prove easier to obtain high quality and consistent management data from farmers.

10.2.6 Social and economic data

Socio-economic monitoring was carried out in the early years (1987-1990) of the English ESAs. Changes to the farm businesses e.g. cropping or livestock systems, in a sample of scheme participants and non-participants were investigated, the financial effects on farmers and on Exchequer were examined, and farmers' attitudes to the scheme were studied (ADAS 1991a; ADAS 1991c; ADAS 1991d). The Environmental evaluation of the Countryside Stewardship Scheme: Module 1 (Carey *et al.* 2001b) had a large socio-economic component. This survey of 500 new CSS agreements assessed the capabilities of the agreement holder to carry out the work prescribed along with ecological and landscape surveys. If the sites were resurveyed the socio-economic impacts could be assessed. An economic evaluation of the CSS was carried out by ADAS and the CCRU of the University of Gloucestershire (Crabb *et al*. 2000) but this work is not be amenable to ecological assessment.

While socio-economic circumstances may well influence whether land enters in the scheme and the choice of prescriptions, it is hard to envisage a major additional effect on vegetation change. Certainly, socio-economic information has not been useful to help to explain change in vegetation with AE schemes to date.

10.2.7 Atmospheric deposition of pollutants

Vegetation is influenced by the deposition of N and sulphur from the atmosphere from industrial and transport sources. It has been shown that there is a correlation between N deposition and shoot N concentration for some herbaceous species, e.g. *Calluna vulgaris* (Pitcairn *et al* 1995; Kirkham 2001). There is also evidence that nitrogen has detrimental effects on some species, particularly bryophytes, lichens and mychorrhizal fungi. *Sphagnum* species are particularly sensitive to even low levels of nitrogen (Bell 1994). Critical levels of N deposition have been identified for different vegetation types, above which botanical change can occur (Grenfelt & Thornelof 1992). Increased nitrogen levels can also interact with other factors such as climatic or grazing stress, or heather beetle *Lochmaea suturalis*, which can exacerbate the negative effects (Heil & Diemont 1983; Kirkham 2001). Temporal trends in S deposition have differed from those of N, with S generally declining in recent years (RGAR, 1997). Interactions between these two plant nutrients may well exist in their effect on vegetation.

Atmospheric deposition data are collected by various bodies including the Atomic Energy Authority. As part of the UK acid deposition monitoring network they collect data on sulphur dioxide, particulate sulphur, nitrogen dioxide, ammonia, nitrous and nitric acid. Nitrogen and sulphur deposition levels have been modelled and mapped for the UK to a 20 km square resolution (RGAR, 1997), and more recent modelling by CEH has produced data, to a 5km resolution. Such resolution is too coarse to establish potential effects of pollutants on individual fields, especially when considering pollutants from point sources, such as pig and chicken units.

It would be valuable to obtain data on the deposition of pollutant nitrogen for monitoring sites, partly to understand failures to maintain low-fertility vegetation, and partly to develop a better understanding of the interactions between N and S deposition, management and vegetation dynamics. If deposition data were to be obtained from only a sub-set of sites, it would be important to ensure that the sample encompassed both a range of habitats – including sites supporting particularly susceptible species - and also the range of deposition levels encompassed by each habitat type.

10.2.8 Discussion

There is a wealth of additional environmental data that can be collected in the field or obtained from national data. However, the record of such data having been used to increase understanding of vegetation change at the agreement or scheme levels is poor: there has been a tendency to collect data in the faith that it will prove useful, rather than collecting data to parameterise specific models or to act as covariates in particular analyses. There is also a grey area here between collecting data necessary for monitoring and for research. Soils, hydrology and management data may well of value in primary monitoring, by indicating change before it becomes apparent in the vegetation. Data from ECN may have a similar role, albeit over much longer timescales. Other data, however, are probably of greater importance for research into factors influencing vegetation dynamics, but only if the research is well specified.