CHAPTER 3

DATA CLASSIFICATION AND POWER ANALYSIS

1 INTRODUCTION

Since the launch of the first AE schemes in 1987, much progress has been made with classifying vegetation and habitats in the UK. For example, the National Vegetation Classification (NVC) for grassland was first published in 1992 (Rodwell 1992), while more recently the Countryside Vegetation System (CVS) was developed for monitoring of change in the wider environment through the Countryside Surveys (CS) of 1978 and 1990 (Bunce *et al.* 1999). Many of the earlier AE monitoring programmes were launched before these developments, although in many cases these classifications have been used subsequently.

UK Biodiversity Action Plan (BAP) Broad and Priority Habitats are presently seen as an important policy framework for the reporting of vegetation change, including that which occurs in AE schemes. Details of BAP Habitats were first published in 1995 (Anon 1995b) – the final round of ESAs was launched prior to this in 1994.

The Countryside Stewardship Scheme (CSS) monitoring programme was set up after the development of the BAP framework and CVS, so both these classification systems were used in the monitoring programme (Carey *et al.* 2001a). The use of land cover data was investigated for allocating ESA monitoring samples to BAP Habitats. However, very few ESA land cover classes were found to be directly related to Priority Habitats (Critchley *et al.* 1999). Moreover, it was also clear that there were Priority Habitats within ESAs for which there was little or no biological monitoring data. The use of CVS for ESA monitoring was also assessed. The agreement between CVS classes and ESA vegetation types was low in most of the lowland grassland sample, but slightly better for upland vegetation (Critchley & Burke 1999).

There are therefore three main objectives in this chapter:

1. The classification of AE botanical datasets into the main frameworks used today for the analysis and reporting of change. This will enable the continued usefulness of the datasets to be assessed.

2. A program of power testing to enable the detectable change to be estimated for different sample sizes.

3. The calculation of sample sizes needed to detect progression towards provisional targets representing pristine and degraded habitats.

2 DATA CLASSIFICATION

2.1 METHODS

ESA monitoring has been carried out using two main techniques; 1m x 1m quadrats were used in the early ESAs, whilst 4m x 8m ADAS plots (Critchley & Poulton 1998) were employed in later ones. In addition, sampling strategy also varied primarily due to local objectives (see Chapter 2). CSS monitoring used two types of nested quadrats; random quadrats were 200m^2 whilst targeted quadrats were of a size appropriate to the vegetation (Carey *et al.* 2001a).

Data were collated from the DEFRA AEMA database and from the CSS database currently held by CEH into three datasets: Countryside Stewardship Scheme (CSS) data, ESA plot data and ESA quadrat data. Only the main grassland and upland botanical datasets were utilised from ESAs. Data from other habitats were excluded (see Appendices 1.1 and 1.2). Also excluded were the Indicative and Extension grassland datasets from the Pennine Dales (because they were not available at the time of the analysis). All data were classified by NVC, CVS and where possible Broad Habitat and Priority Habitat. In addition, GIS information was used classify the data to county level (for categorisation by Region), and to determine the correspondence, if any, of AE plot/quadrats with statutory designations (*e.g.* SSSI, SAC *etc.*). Classifications were slightly different for each dataset.

2.1.1 National Vegetation Classification (NVC)

CSS data had been classified previously using a program (SIMIL) provided by the Unit of Vegetation Science at the University of Lancaster (Carey *et al.* 2001a). SIMIL works in a similar way to the MATCH (Malloch 1992) program, using species abundance or frequency data to calculate similarity coefficients for each plot based upon their similarity to NVC constancy tables.

The ESA plot data had also previously been classified to NVC level and this information was also used. However, three plots had no NVC information (two in the Lake District ESA and one in the South Wessex Downs ESA), and in one ESA (Clun) the majority of plots had not been classified to one NVC level.

The ESA quadrat data had been classified using Twinspan (Hill 1979) and the NVC communities or sub-communities of the end-groups determined using a combination of MATCH (Malloch 1992) and constancy tables. Individual quadrats had not been directly classified into the NVC.

NVC classification of the missing ESA plot data and the ESA quadrat data was therefore carried out using the SIMIL programme. Classification of these data provided the top ten matches with a similarity score (0-100%). Generally, the top score was chosen, particularly if it was high (> 60%). However, the scores were often very low, in which case the frequency of occurrence of NVC communities in the SIMIL output for a quadrat or plot was also referred to (*e.g.* a single plot may be categorised to MG6, MG6a and MG6b). If two NVC communities were found to be equally frequently recorded, in the output, then that with the higher similarity score was chosen. Occasionally, a plot would have a very high score (*i.e.* > 50%) for a particular community – this was almost always also the most frequent community. Some allowances were made for vegetation types where there were no sub-communities, *e.g*. MG8, and in those cases where the classification was thought to be particularly unusual; for example SD17 (*Potentilla anserina – Carex nigra* dune-slack community) appeared a number of times. Rodwell (2000) indicates that this community is very similar to MG8 (*Cynosurus cristatus – Caltha palustris* grassland) and it is possible that the lack of/inclusion of a single species can change the classification of such plots/quadrats significantly. For the purposes of this project, samples were only classified to community level.

2.1.2 Countryside Vegetation System (CVS)

The existing classification of CSS data into the CVS was used. CVS classification of ESA data was carried out using a program developed by CEH and available on the Internet at:

http://www.ceh-nerc.ac.uk/products_services/software/cvsflier.htm

The program allocates plots and groups of plots to one of the hundred vegetation classes that make up the classification. A full list of classes and their descriptions can be found in Bunce *et al.* (1999). Allocation of plot data uses a binary decision tree developed from the original Twinspan classification of the Countryside Survey plots recorded in 1978 and 1990. The program does not use cover or constancy data to allocate plots.

2.1.3 BAP Broad Habitat

Classification by Broad Habitat was done using the tables produced by the Joint Nature Conservation Committee (JNCC) (Jackson 2000). Many NVC categories had one core vegetation class and one or two associated classes, whilst some had more than one core class. If an NVC had more than one core class, it was deemed to be unclassifiable. This mainly affected the MG6 group (found in Neutral Grassland and Improved Grassland), but also M25 (found in Fen, Marsh & Swamp and Bogs).

The most frequently recorded associated classes were Boundary & Linear Features and Built Up Areas & Gardens. These were discounted as the data being classified was from AE schemes and so these features were unlikely to be represented. However, a few NVC communities had an associated vegetation type that might be found in an AE scheme; M16 was found in the core vegetation of Dwarf Shrub Heath but also in the associated vegetation of Bogs. These communities were also unclassified.

This exercise was carried out for all datasets, even though land cover data (in the case of ESAs) and Habitat data (in the case of CSS) were also available. This was partially so that all data could be treated equally, but also because of the influence of scale on the classification. The ESA land cover information and the CSS Habitat data were carried out at a different scale than the allocation of individual plots to Broad Habitats by NVC. A comparison of the original CSS BAP classification with that determined by NVC was carried out.

2.1.4 BAP Priority Habitat

Classification by Priority Habitat using the NVC alone was more problematical as some habitats are at least partially defined by their landscape context. However, from the Tranche 1 Actions Plans (Anon 1995b) and the Tranche 2 Action Plans downloaded from the internet (Anon 1998, 1999), http://www.ukbap.org.uk), it was possible to classify eight priority habitats using the NVC (see Table 1). In addition the Purple Moor Grass & Rush Pastures Priority Habitat was classified using the information detailed in Burke & Critchley (2001).

Table 1. BAP Priority Habitats and associated NVC communities.

Priority Habitat	**Vegetation types**
Lowland Calcareous Grassland	CG1 – CG8, CG9[1]
Upland Calcareous Grassland	CG9[1], CG10 – CG14
Lowland Dry Acid Grassland	U1[1], U2[1], U3[1], U4[1], SD10b[2], SD11b[2]
Lowland Meadows	MG4, MG5, MG8
Upland Hay Meadows	MG3
Lowland Raised Bog	M1 – M3, M18 (M15, M19, M20, M25, U4)[3]
Blanket Bog	M1 – M3, M15, M17 – M20, M25
Upland Heathland	H4[1], H8[1] – H10, H12, H16, H18, H21, M15, M16
Purple Moor Grass & Rush Pastures	M22 – M26

[1] Straddles lowlands and uplands

[2] Inland examples only

[3] These five communities *may* be found in Lowland Raised Bog

No core vegetation communities of Lowland Raised Bog (M1 – M3, M18) were recorded in the datasets. CG9 (*Sesleria albicans – Galium sterneri* grassland) is indicated as occurring in both lowlands and uplands. One only example was found of this community, in the Pennine Dales ESA, and as a result it was not included in the analyses. M25 (*Molinia caerulea – Potentilla erecta* mire) is a core vegetation of both the Fen, Marsh & Swamp Broad Habitat and the Bogs Broad Habitat. Therefore, as well as occurring in the Blanket Bog Priority Habitat (associated with the Bogs Broad Habitat), it could also occur in one of the Priority Habitats associated with Fen, Marsh & Swamp which include the Purple Moor Grass & Rush Pastures Priority Habitat. The M25 records were therefore left unclassified. Such a situation also affected other mire communities; M15 (*Scirpus cespitosus – Erica tetralix* wet heath) was recorded in both Blanket Bog and Upland Heathland Priority Habitats, for instance.

2.2 RESULTS

2.2.1 NVC classifications

From the 533 CSS plots classified, seventy-seven NVC categories were recorded but only six contained twenty or more records (twenty being the cut-off used for power testing). There were seventeen quadrats of CG2 for example and only two of MG3 (upland hay meadow). Of the six communities with greater than twenty records (Table 2), five were mesotrophic grasslands, with MG6 clearly the most frequent, representing nearly 20% of the CSS dataset; this was followed by MG5 and MG7. The sixth community was OV23 (*Lolium perenne – Dactylis glomerata* community), a community of coarse weedy vegetation in which the two grass species make up the bulk of the vegetation. Together, all six communities accounted for 54.5% of the data. In total mesotrophic grassland (MG) made up 58% of the data, whilst OV communities accounted for another 13%.

Table 2. Most frequently recorded NVC vegetation types in CSS.

Community	**Name**	***n***
MG6	*Lolium perenne – Cynosurus cristatus* grassland	106
MG5	*Cynosurus cristatus – Centaurea nigra* grassland	68
MG7	*Lolium perenne* leys and related grasslands	48
MG10	*Holcus lanatus – Juncus effusus* rush-pasture	26
MG1	*Arrhenatherum elatius* grassland	22
OV23	*Lolium perenne – Dactylis glomerata* community	21

Thirty-eight NVC categories were recorded from the 1614 records in the ESA quadrat dataset, with nearly 90% of the quadrats classified as mesotrophic grassland. Calcareous grasslands were the next most frequent, but they accounted for less than 4%. Overall, the most frequent community was MG7 (Table 3), followed by MG10 and MG6. Only ten NVC categories contained twenty or more quadrats; CG3 (*Bromus erectus* grassland) and OV23 (*Lolium perenne – Dactylis glomerata* community) were the only two non-mesotrophic grassland communities in this list and accounted for 2.4% and 1.5% respectively. The OV23 community occurs on mesotrophic and eutrophic soils in areas that have been re-seeded and that are generally subject to infrequent management, other than periodic mowing (Rodwell 2000). Nearly 3% of the data were classed as OV vegetation.

Table 3. Most frequently recorded (> 20 quadrats) NVC vegetation types in ESA quadrat data.

Community	**Name**	***n***
MG7	*Lolium perenne* leys and related grasslands	549
MG10	*Holcus lanatus – Juncus effusus* rush-pasture	312
MG6	*Lolium perenne – Cynosurus cristatus* grassland	230
MG11	*Festuca rubra – Agrostis stolonifera – Potentilla anserina* grassland	99
MG9	*Holcus lanatus – Deschampsia cespitosa* grassland	94
MG13	*Agrostis stolonifera – Alopecurus geniculatus* grassland	50
CG3	*Bromus erectus* grassland	39
MG1	*Arrhenatherum elatius* grassland	34
MG8	*Cynosurus cristatus – Caltha palustris* grassland	32
OV26	*Epilobium hirsutum* community	24

Of the 591 ESA plots, thirty-three NVC communities were recorded with mesotrophic grasslands the best represented (62%) followed by upland grassland communities (14%) and mires (10%). Calcareous grasslands made up 9% of the data. Only nine communities contained greater than or equal to twenty records (Table 4). MG6 was the single largest group (144 records, 24%), followed by MG7 and MG5. However, communities such as U4, CG2 and H4 were also represented (8%, 6% and 3% respectively). There was no OV vegetation represented in the ESA plot data.

Table 4. Most frequently recorded (≥ 20 quadrats) NVC vegetation types in ESA plot data.

Community	**Name**	***n***
MG6	*Lolium perenne – Cynosurus cristatus* grassland	144
MG7	*Lolium perenne* leys and related grasslands	63
MG5	*Cynosurus cristatus – Centaurea nigra* grassland	52
U4	*Festuca ovina – Agrostis capillaris – Galium saxatile* grassland	47
MG10	*Holcus lanatus – Juncus effusus* rush-pasture	39
CG2	*Festuca ovina – Avenula pratensis* grassland	36
MG9	*Holcus lanatus – Deschampsia cespitosa* grassland	35
M23	*Juncus effusus/acutiflorus – Galium palustre* fen-meadow	22
H4	*Ulex gallii – Agrostis curtisii* heath	20

Mesotrophic grassland communities were highly frequent in all three datasets accounting for 75% of the combined records, but there were relatively more in the ESA quadrats (88%) than in ESA plots (62%) and in the Countryside Stewardship Scheme (58%), (Figure 1). However, the CSS data contained a lot of OV communities, whilst the ESA plots contained none. This is a reflection of the nature of the datasets. The Countryside Stewardship monitoring contained a proportion of random plots in addition to plots targeted at priority habitats, whilst the ESA monitoring was targeted at particular vegetation types or tiers depending on local objectives. The CSS data and the ESA plots also contained a number of records classified as heath vegetation, a type that was absent in the ESA quadrats. Mire and montane communities were also relatively poorly represented in this dataset.

A number of minority communities were also found in the three datasets, including Aquatic, Maritime Cliff, Sand Dune and Salt Marsh communities (Figure 1). Most of these communities (twenty-one of twenty-three) were from the CSS data.

Full details of communities recorded can be found in Appendices 1.3 and 1.4.

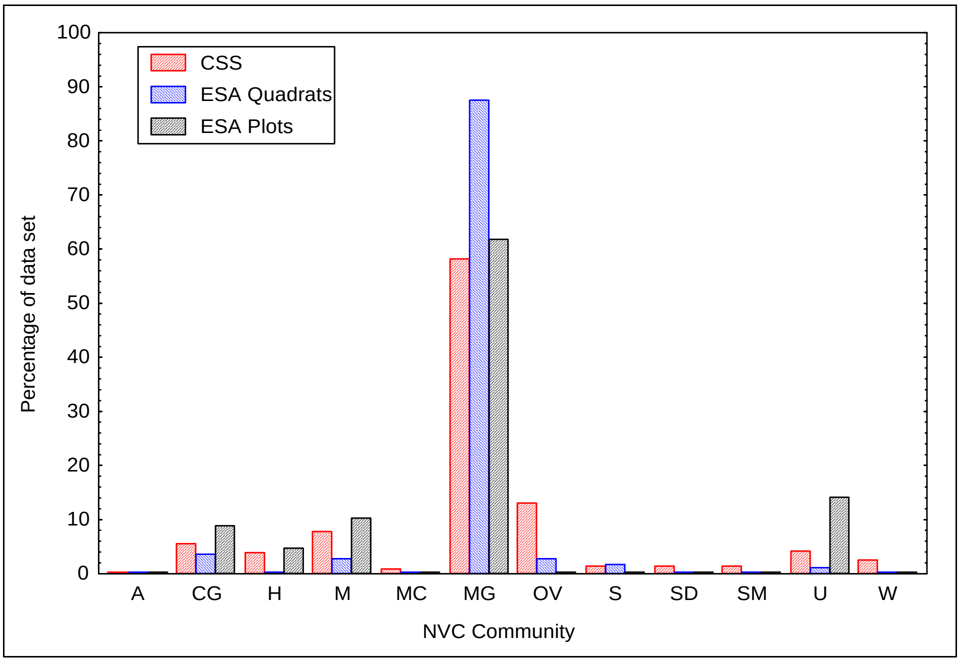

Figure 1. Representation of vegetation classes in the three datasets.

2.2.2 CVS classification

Sixty-one CVS vegetation classes were recorded from the CSS data with the highest number (113, 22%) from the Rye-grass/Yorkshire Fog grassland category (class 40). Five classes contained twenty or more plots and these were all from two aggregate classes, Fertile Grassland and Infertile Grassland (Table 5). In addition, these two aggregate classes accounted for 74% of the plots overall.

Table 5. Most frequently recorded CVS vegetation types in CSS.

Aggregate class	**Vegetation class**	**Community**	***n***
4	40	Rye-grass/Yorkshire-fog grassland	113
3	30	Fertile mixed grassland	80
4	44	Calcareous grassland	38
4	43	Rye-grass/Bent Grass grassland	34
4	51	Wet rushy grassland	24

Thirty-seven different CVS vegetation types from nine aggregate classes were recorded in the ESA quadrat data, but Fertile mixed grassland and Rye-grass/Yorkshire Fog grassland made up the majority of the vegetation at over 55%. Wet rushy grassland accounted for another 14%. Only nine classes contained 20 or greater records (Table 6).

Table 6. Most frequently recorded CVS vegetation types in ESA quadrat data.

Aggregate class	**Vegetation class**	**Community**	***n***
3	30	Fertile mixed grassland	484
4	40	Rye-grass/Yorkshire-fog grassland	411
4	51	Wet rushy grassland	219
4	43	Rye-grass/bent grass	141
4	44	Calcareous grassland	76
3	29	Rye-grass grassland	66
3	31	Rye-grass/clover G	42
2	10	Tall grassland/herb boundaries	24
4	41	Species-rich stream-sides/wet grassland	20

Forty CVS vegetation classes were recorded from the ESA plot data with seven having twenty or more records. The Rye-grass/Yorkshire Fog grassland category was the most abundant (Table 7). Fertile mixed grassland and Calcareous grassland were also well represented and, in addition, Wet heath/moorland grass and Bracken/acid grassland were also present.

Table 7. Most frequently recorded CVS vegetation types in ESA Plot data.

Aggregate class	**Vegetation class**	**Community**	***n***
4	40	Rye-grass/Yorkshire-fog grassland	164
3	30	Fertile mixed grassland	69
4	44	Calcareous grassland	67
4	51	Wet rushy grassland	51
8	90	Wet heath/moorland grass on variable soils	25
3	31	Rye-grass/clover grassland	23
6	64	Bracken/acid grassland	20

A comparison of the CVS vegetation classes was difficult due to the large number and wide range found. However, Table 8 shows the data broken down by aggregate class. Infertile grassland in all three datasets occurred at a similar level and accounted for over 56%. However, the ESA quadrat data contained more Fertile grassland, whilst the CSS data had more Tall grassland/herb data, although the numbers were relatively low. Heath/bog did not occur in the ESA quadrats but was relatively frequent in the ESA plot and the CSS data, Moorland grass/mosaic was also uncommon in the ESA quadrats. Overall, the CSS data contained a wider range of classes than the other two datasets.

The single largest CVS class was class Rye-grass/Yorkshire-fog grassland (class 40) with 688 records, followed by Fertile mixed grassland (class 30, 633 records). However whereas the former occurred at a relatively high frequency in all three datasets, the latter was found mainly in the ESA quadrat dataset. The other two largest classes Rye-grass/bent grass grassland and Neutral grassland (classes 43 and 51 respectively) also had a large component from this data source. Complete lists of the CVS categories recorded can be found in Appendices 1.5 and 1.6.

Table 8. Percentage of Records by CVS Aggregate class in CSS and ESA Quadrat and Plot data.

CVS Aggregate Class		CSS	ESA quadrats	ESA plots	Mean
I	Crops/Weeds	1.50	0.06	0	0.52
II	Tall Grassland/Herb	7.50	4.09	0.17	3.92
III	Fertile Grassland	21.58	37.24	16.75	25.19
IV	Infertile Grassland	52.53	57.50	58.21	56.08
V	Lowland Wooded	1.50	0	0	0.50
VI	Upland Wooded	4.32	0.06	3.38	2.59
VII	Moorland Grass/Mosaic	6.38	1.05	10.83	6.09
VIII	Heath/Bog	3.94	0	10.66	4.87
	Unclassified	0.75	0	0	0.25

2.2.3 BAP Broad and Priority Habitats

Of the 533 quadrats in the CSS data, only 353 (66%) were classified according to BAP Broad Habitat (Table 9). Of the ESA quadrat data, Broad Habitat categories could be assigned to 82% records, whilst 70% of the ESA plot data was classified. Many of the quadrats and plots remained unclassified as they fell into more than one Broad Habitat (as determined by NVC). Other NVC classes (such as the OV classes) were not possible to assign to Broad Habitats.

Table 9. All recorded Broad Habitats (as classified by NVC) in CSS and ESA quadrats and plots.

Broad Habitat	CSS	ESA quadrats	ESA plots	Total
Neutral Grassland	156	635	158	949
Improved Grassland	48	549	63	660
Fen, Marsh & Swamp	47	61	24	132
Calcareous Grassland	29	59	52	140
Acid Grassland	22	17	84	123
Dwarf Shrub Heath	20	0	27	47
Supra-littoral Sediment	8	1	0	9
Littoral Sediment	7	0	1	8
Supra-littoral Rock	5	0	0	5
Broad-leaved, mixed and yew woodland	3	0	0	3
Bracken	3	0	2	5
Bogs	2	0	5	7
Inland Rock	2	0	0	2
Water	1	0	0	1
Unclassified	180	292	175	647

Fourteen Broad Habitats were identified in the CSS data with Neutral and Improved grasslands the best represented – Neutral Grassland alone accounted for 29% of the quadrats (44% of the classified sample). Only five Broad Habitats had twenty or more quadrats.

It was possible to assign Priority Habitat status (based on NVC) to 129 plots (22% of the sample, see Table 10) and of these Lowland Meadows was the largest group (seventy-six quadrats) followed by Lowland Calcareous Grassland (twenty-six quadrats).

Table 10. All recorded Priority Habitats (as classified by NVC) in CSS and ESA quadrats and plots.

Priority Habitat	**CSS**	**ESA quadrats**	**ESA plots**
Lowland Meadows	76	32	67
Lowland Calcareous Grassland	26	58	52
Lowland Dry Acid Grassland	11	15	61
Upland Calcareous Grassland	3	0	0
Upland Hay Meadows	2	2	0
Upland Heath	9	0	27
Blanket Bog	2	0	5
Unclassified	415	1507	411

In the ESA quadrat data, out of six identified Broad Habitats, Neutral grassland and Improved grassland were the most common (73% of the total, 90% of the classified sample, Table 9). From this, four Priority Habitats were identified; Lowland Calcareous Grassland, Lowland Meadows, Lowland Dry Acid Grassland, Upland Hay Meadows. Only 139 quadrats (8%) could be classified to Priority Habitat level and only the first two habitats contained at least twenty records – the Upland Hay Meadows Priority Habitat contained only two (Table 10). Coastal and Floodplain Grazing Marsh could not be identified because it is dependent on the geographic location, and encompasses other Priority Habitats and more than one Broad Habitat.

Nine Broad Habitats were recorded from the ESA plot data (Table 9), but only three Priority Habitats. Neutral grassland accounted for 27% (of the total) with Acid grassland equivalent to 14% (of the total). Only 180 plots (30%) could be classified down to Priority Habitat level (Table 10). Lowland Meadows was most frequent (67 plots) followed by Lowland Dry Acid Grassland (61 plots) and Lowland Calcareous Grassland (52 plots).

The CSS dataset had the widest range of Broad Habitats identified, with the ESA quadrats the least. However, the Neutral Grassland Broad Habitat, was the most frequent in all three datasets, and was highest in ESA quadrats and least in ESA plots. The ESA quadrats also had a larger number of Improved grassland records, such that these two categories made up 90% of the data, although all three datasets had similar amounts of Improved grassland (14-15%). The CSS data had a higher number of Fen, marsh & swamp records, whilst the ESA plots had a greater amount of Acid grassland. No Dwarf Shrub Heath Broad Habitat was found in the ESA quadrats, but it was recorded in the CSS dataset and in the ESA plots (6% in both cases).

The majority (74%) of unclassified quadrats and plots had been classed as MG6 grassland (Table 11). The remainder was a mixture of OV, M, S and W communities representing a range of Broad Habitats.

Table 11. Table. AE quadrats and plots not able to be classified to a single Broad Habitat level. A&H = Arable & horticulture, B&L = Boundary & linear features, BMW = Broad-leaved, mixed and yew woodland, Bogs = Bogs, BUA = Built-up areas and gardens, CW = Coniferous woodland, DSH = Dwarf shrub heath, FMS = Fen, marsh & swamp, IG – Improved grassland, NG – Neutral grassland, OW = Standing open water & canals and R&S = Rivers and streams.

NVC	Broad Habitat	CSS	ESA quadrats	ESA plots	Total
MG6	IG, NG	106	230	144	480
OV	A&H, CW, B&L, BUA	56	21	0	77
M	B&L, FMS, Bogs, DSH	11	9	31	51
S	FMS, OW, R&S	0	29		29
W	BMW, B&L	7	3	0	10
Total		180	292	175	647

In total, seven Priority Habitats were recorded from the data. All were recorded in the CSS data, with the least number of habitats recorded from the ESA plots. In general lowland communities were better represented than upland communities. All three lowland communities were found in similar numbers in the ESA plot data, whereas the CSS data had a large number of Lowland Meadows and the ESA quadrats a large number of Lowland Calcareous Grasslands. Lowland Dry Acid Grassland was found only at low levels and in both the CSS and the ESA quadrat data. However, the ESA plot data did have a larger number of Upland Heaths than the other two data sources. None of the upland communities were identified in the ESA quadrat data.

It is possible that more of the samples could be classified as Priority Habitat with the use of additional spatial data perhaps using a GIS. This might at least help determine where to place samples that could fall into more than one Priority Habitat based on NVC community. An example would be the use of the MAFF moorland line to split upland and lowland habitats (e.g. upland heath and lowland heath and blanket bog and purple moor-grass and rush pastures).

2.2.4 Government Office Regions and Statutory Designations

Although grid references were used to determine this information, for the ESA grassland data, many grid references in AEMA were either missing or incomplete. However, some ESAs, such as the Clun ESA, are entirely in one region, whereas the Pennine Dales ESA is split between three regions (North West, North East and Yorkshire and Humberside); this allowed the more records to be categorised than would otherwise be possible. Some grid reference information was also missing from the CSS data. It is understood that work has subsequently been done to input and correct grid references in AEMA, which would enable the classification to be completed.

Table 12 shows the number of records in each scheme in the various Government Office Regions. The majority of the unclassified ESA quadrat data was from the

Pennine Dales ESA, whereas unclassified data in the ESA plots dataset were from the Avon Valley and South Wessex Downs ESAs. Data for the ESA quadrats are based upon the number of fields, not the number of quadrats.

Whilst CSS data were from all the English regions, the majority was in the South West and South East Regions. The ESA data are obviously biased due to the location of individual ESAs. Quadrat data were recorded from only six of the twenty-two ESAs found in England and so none were recorded from either the West Midlands or East Midlands regions. ESA plots were not recorded from either the North East, Yorkshire and Humberside or Eastern regions – three areas where the Tranche 1 ESAs were launched. Overall, therefore, the South West clearly has the greatest concentration of AE botanical monitoring sites (27%) followed by the South East and Yorkshire and Humberside (both approximately 15%). The East Midlands region had the least number of sites (3%). Unclassified data accounted for 7% of the total.

Table 12. Number of quadrats and plots in the three schemes in each Government Office region. ESA quadrat figures are based on the number of fields, not the number of quadrats.

Government Office region	**CSS**	**ESA quadrats**	**ESA plots**	**Total**
North East	26	162	0	188
North West	36	59	24	119
Yorkshire & Humberside	63	226	0	289
West Midlands	50	0	138	188
East Midlands	51	0	8	59
Eastern	61	99	0	160
South West	132	100	309	541
South East	104	110	82	296
Unclassified	3	109	30	142
Total	526	865	591	1982

The missing/incomplete grid references presented a greater problem for the classification by statutory designations. Only 545 of the 865 fields with ESA quadrats could be classified (63%). This compares with 75% for ESA plots and 99% for the CSS data (see Table 13).

Of the CSS data, eighty-three sites had statutory designations, of which all were SSSIs. Of these, a further twenty-one sites were SPAs and thirteen of these were also Ramsar sites. Nineteen of the eighty-three sites were SACs and two were NNRs. However, in some cases, some of these designations refer to the same holding.

Many more of the ESA grassland sites had a statutory designation than the CSS sites. This is reflects the targeted nature of ESA scheme, whereas CSS monitoring was random (in terms of site selection) and partially random (in terms of plot selection). However, no ESA grassland sites appeared to coincide with NNR sites, whereas two of the CSS sites did.

Over 66% of the ESA quadrats were SSSIs compared to 22% for the ESA plots and less than 16% of the CSS data. SACs were the next most frequent designation, although the table (Table 13) clearly shows that they were relatively less frequent in the CSS and ESA plot data. However, the widest range of designations was found in CSS, with all five designations recorded; the ESA quadrats had the least – only SSSIs, SACs and SPAs were recorded here. Ramsar sites are poorly recorded in agri-environment schemes. This is firstly because the definition of wetlands as “areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres" (Convention on Wetlands, Ramsar, Iran, 1971), means that little of it would be found in AE schemes and secondly because only 79 Ramsar sites have so far been designated in England (Anon. 2002).

Table 13. Number of statutory designations found in the CSS and ESA quadrat and plot datasets.

Statutory designation	**CSS**	**ESA quadrats**	**ESA plots**	**Total**
SSSI	49	155	61	265
SSSI NNR	1	0	0	1
SSSI SAC	12	125	25	162
SSSI SPA	6	0	6	12
SSSI SAC SPA	2	80	0	82
SSSI SPA RAMSAR	8	0	8	16
SSSI SAC SPA RAMSAR	4	0	0	4
SSSI SAC SPA RAMSAR NNR	1	0	0	1
Total designated sites	83	360	100	543
Total classifiable	523	545	449	1517

No Ramsar sites were recorded in ESA datasets but thirteen were found in the CSS dataset, although some of these were on the same holding. However, the Avon Valley is a Ramsar site designated on 02/02/1998 and encompasses the lower reaches of the Avon between Bickton and Christchurch and thus would cover the same area as part of the Avon Valley ESA. However, this ESA was also one where only incomplete grid references were available. This problem also seems to effect the Broads ESA and the Somerset Levels and Moors ESA parts of which are covered by the Broadland and Somerset Levels and Moors Ramsar sites.

2.2.5 Comparison of CSS BAP classifications

In the current study, the allocation of CSS plots to BAP Habitats was carried out using NVC classifications only. Allocation of CSS plots to BAP Broad and Priority Habitats was also carried out in the field at the time of survey and whilst there is some correspondence between the two classifications, overall it is quite poor (see Appendix 1.7). In addition, some of the categories originally allocated in the field survey were combinations of more than one habitat, for example ‘Lowland Dry Acid Grassland/Upland Heath’. Some groupings showed better correspondence than others did. Of the twenty-nine plots classed as Calcareous Grassland based on their NVC, twenty-four of them had originally been identified as being that Broad Habitat, with the remainder a variety of communities including Improved Grassland and the combination of Broad-leaved Mixed Woodland/Calcareous Grassland.

The Cereal Field Margins Broad Habitat was not used or identified in the current work. Thirty-six examples of it had been found which, when the plots were classed by NVC, where either left unclassified for Habitat (many of the OV communities), or were categorised mainly as either Neutral Grassland, Improved Grassland or Fen, Marsh and Swamp.

The Neutral Grassland group as classed by NVC, corresponded with twenty-five of the original vegetation classes – but only 3% of the group were in the original Neutral Grassland class; 44% were in the Improved Grassland Broad Habitat and 16% in the Calcareous Grassland / Lowland Calcareous Grassland classes.

Only two of the plots had been placed into the Purple Moor Grass & Rush Pasture Priority Habitat at the time of survey. As classed using NVC, these came out as Fen, Marsh & Swamp or Neutral Grassland.

In formulating the future recommendations for monitoring (Chapter 4), the NVC classifications have been used to allocate existing samples to BAP habitats. This ensures that a standard approach has been applied across all the datasets. However, there will be instances where a quadrat or plot is located in a particular habitat, but the quadrat or plot data are classified as a different habitat due to differences in spatial scale. In neither NVC nor BAP is spatial scale well defined, because patch size varies for plant communities and habitats. Potentially, individual samples could be allocated to BAP habitats at the two different scales, i.e. at the plot or quadrat scale using the NVC classification of the botanical data, and at scale of the whole site or vegetation patch using a habitat classification as was done in CSS.

3 POWER ANALYSIS

3.1 METHODS

3.1.1 Community variables

In the CSS data, bryophyte and lichen species were frequently recorded. In the ESA data, lichens and bryophytes were rarely recorded except where certain species or groups were of concern *e.g. Sphagnum* species. All lichen and bryophyte species records were therefore deleted from all datasets before analysis.

The following community variables were calculated; species richness, British Ellenberg Nitrogen and G and Nu suited species scores. Suited species scores were developed for the evaluation of vegetation in ESA monitoring relative to ESA management prescriptions, objectives and performance indicators. The relevant ecological conditions are identified and species can then be classified according to a set of criteria. Analysis of these 'suited-species' can subsequently be carried out based on the changes in the proportions of these species. A single species can have a status for a particular criterion of –1, 0 or +1 (Critchley *et al.* 1996b; Critchley 2000).

The G score (species suited to grazing) uses information on canopy height and structure and on life history to determine suited-species (Table 14). The higher the score, the higher the level of grazing. The Nu score uses information on Stress radius (Grime *et al.* 1988), Ellenberg Nitrogen Index (Ellenberg 1988), Fertility score (Wheeler & Shaw 1992) and Ecoflora Fertility (Fitter & Peat 1994). A high Nu score represents a high nutrient availability.

Table 14. Definitions and ecological information required for the G and Nu scores.

Criterion	**Definition**	**Data sources/information**
G score	Grazing	Canopy height/structure, life history
Nu score	Soil fertility	Stress radius, Ellenberg N Index, Ecoflora Fertility

The average British Ellenberg Nitrogen scores were calculated with the species values taken from Hill *et al.* (1999).

Quadrats in the CSS dataset were of two types, Random and Targeted (see Carey *et al.* 2001a). In the random quadrats, species were recorded according to the nest and the cover of all species was estimated over the 200m^2 in 5% bands. In the targeted quadrats, presence/absence was recorded only for all species. As a result, all community variables were weighted by presence/absence.

In the ADAS plot method (Critchley & Poulton 1998), a fixed 4m x 8m plot is established, containing 32 x 1m x 1m nests. Species are recorded from within these nests at different scales (1-10) with scale 1 being a random pin hit in the smallest nest (2cm x 2cm). This was used in all ESAs except the Cotswold Hills ESA where 2m x 4m nests were used resulting in 32 x 0.5m x 0.5m nests. Community variables were calculated at maximum scale (scale 10, equivalent to presence/absence) and at optimum scale. Species richness and Ellenberg N were calculated at scale 10 (i.e. $1m^2$).

Burke & Critchley (1999) had previously found that it was possible to record from only sixteen nests from an ADAS plot without unduly compromising sensitivity. As a result, community variables were calculated for thirty-two nests and for sixteen nests. Data for nest numbers 1-16 in each plot were used for the latter.

Quadrats in ESAs were 1m x 1m and species were recorded from them using the Domin scale. All community variables were calculated at the presence/absence level whilst G and Nu scores were additionally calculated using Domin weighting.

Optimum scale data was used for the power analysis of the ESA plot data; both Domin weighting and presence/absence weighting were used in the analysis of the ESA quadrat data.

3.1.2 Power testing

To get some idea about the magnitude of change that can be detected for a given sample size a series of power calculations have been conducted. These were done 1) using variability between plots or quadrats in one year of survey and 2) using variability of the difference between repeated surveys. For this purpose the standard deviation of the difference (SD diff) has been used. It is assumed that this will also be typical of surveys done in the future. For any given variable the SD diff varies considerably so power calculations have been undertaken at average SD diff as well as for the smallest and largest observable values of SD diff. Using this information the magnitude of change has been calculated that could be detected for a range of different sample sizes and these results tabulated.

Calculations were done using Minitab software.

3.2 RESULTS

The CSS data showed the widest range of species richness whilst the ESA grassland quadrat and plot data exhibited similar ranges. However, all three datasets had a modal species richness in the 10-20 range. Lowest G scores were observed in the CSS dataset, whilst high G scores were recorded in both ESA datasets. The CSS dataset also had low Nu scores, along with the ESA plot data, whilst high scores were recorded in the ESA quadrat dataset.

British Ellenberg Nitrogen indices exhibited similar trends to the Nu scores. They were also highly correlated, with r^2 = 89% for the CSS data, for example. This is not surprising as the Nu score incorporates some information on species' Ellenberg N values.

The correlations of Nu and British Ellenberg N index were also significant for ESA quadrats (r^2 = 80% for presence/absence; r^2 = 32% for Domin weighted data) and ESA plots(r^2 = 92% at optimum scale; r^2 = 80% at scale 10).

There was little difference between the results from ESA plots for thirty-two nests and the results for sixteen nests. Correlations of the data between thirty-two and sixteen nests showed that for species richness and Nu score, r^2 = 98%, whilst for British Ellenberg N, r^2 > 99%. The G score gave the poorest correlation although it was still highly significant (r^2 = 89%).

3.2.1 Single surveys

The CSS data consisted of 533 samples, ESA plot data 591 samples and ESA quadrat data 1614 samples.

The desire is to detect change if it occurs in the community variables when sites are categorised by NVC class, CVS class, Broad Habitat or Priority Habitat. Appendices 1.8-1.11 summarise the means and standard deviation by these categories for each variable and each source of data. Results are limited to categories where at least 20 samples were present. This still presents an enormous quantity of results and standard deviations (sd) have been summarised (across categories) further in the following table.

Table 15. Summary of standard deviations across all categories.

	Mean sd	**Smallest sd**	**Largest sd**
Richness (n=96)	5.138	1.344	11.869
Ellenberg N (n=96)	0.479	0.195	1.238
Nu (n=122)	0.168	0.076	0.461
G (n=122)	0.147	0.045	0.409

The power of a test can be defined as the ability (probability) of the test to declare a result as significant when a true change has occurred. In the following examples a power of 85% is used, i.e. when true differences occur we have a 85% probability of detecting them. To simplify presentation, power curves have been calculated for the smallest, mean and largest sd based on a two sample t-test (e.g. random quadrats at two time points).

Figures 3-6 represent the situation for differences in species richness, British Ellenberg N, Nu score and G score respectively. These provide a guide to the likely sample size necessary to detect a given difference if a random sample or plots or quadrats was to be re-selected at each survey. For example, in an average situation, a sample size of 10 could detect differences of 7.3, 0.68, 0.24, and 0.21 with 85% power respectively for the four variables.

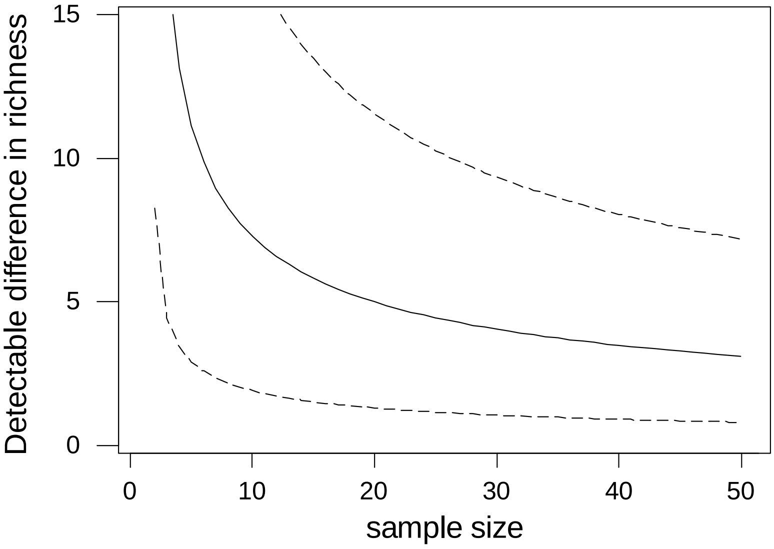

Figure 2. Detection differences in species richness for various sample sizes based on three sd situations; minimum sd (lower line), mean sd (solid line) and maximum sd (upper line).

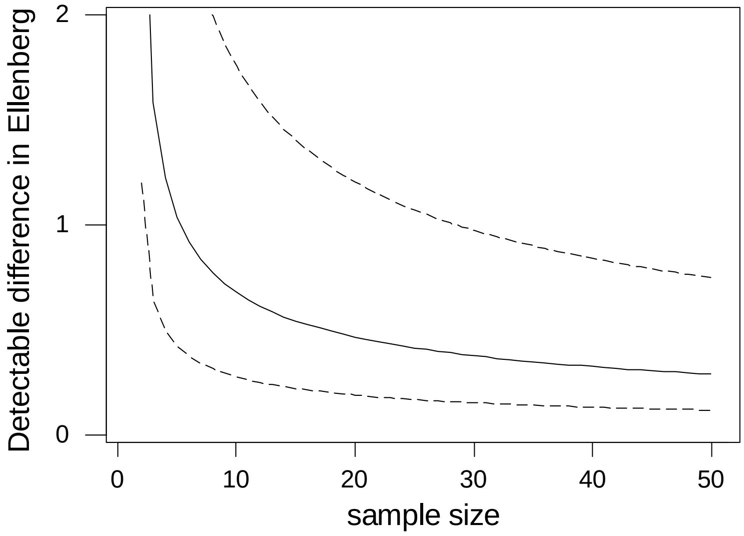

Figure 3. Detection differences in Ellenberg N for various sample sizes based on three sd situations; minimum sd (lower line), mean sd (solid line) and maximum sd (upper line).

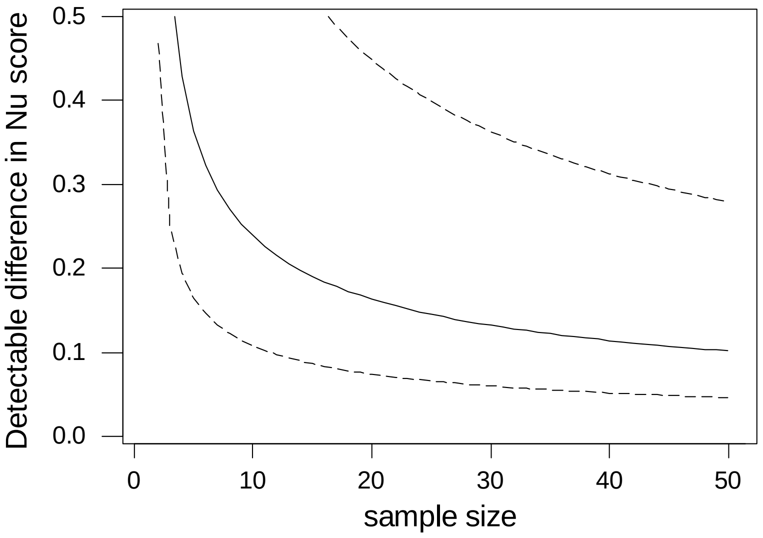

Figure 4. Detection differences in Nu score for various sample sizes based on three sd situations; minimum sd (lower line), mean sd (solid line) and maximum sd (upper line).

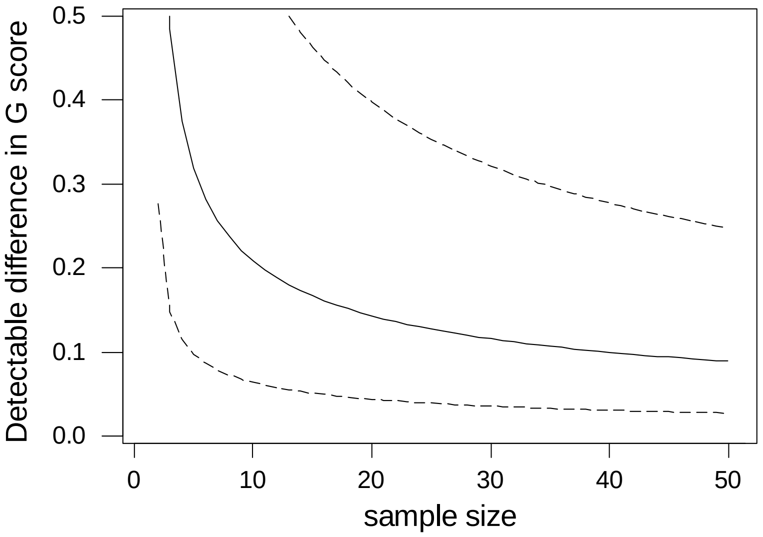

Figure 5. Detection differences in G score for various sample sizes based on three sd situations; minimum sd (lower line), mean sd (solid line) and maximum sd (upper line).

However, in AE monitoring programmes, permanent plots or quadrats have mostly been used rather than random quadrats at each of two time points. The data used here to estimate variability are measuring spatial variability within a category rather than temporal variability between the same positions. Measurements of the same quadrat at discrete time points are likely to be more correlated than would two random quadrats and an adjustment is necessary. The likely method of analysis between two years in this situation is the paired t-test rather than the two sample t-test used for the above figures.

For species richness and British Ellenberg N, the following show how correlation within a quadrat over time improves the level of change that can be detected. Calculations have been based on correlation coefficients of 0.5, 0.7 and 0.9. Figure 6 and Figure 7 show the situation for average sd with random quadrats (identical to the solid line in Figures 3-6) and for paired quadrats where the autocorrelation is 0.5, 0.7 and 0.9. It is clear that at high autocorrelation the detection difference for a given sample size can be halved. As an example the difference detectable for British Ellenberg N at sample size 10 is 0.51, 0.40 and 0.23 for the three levels of autocorrelation.

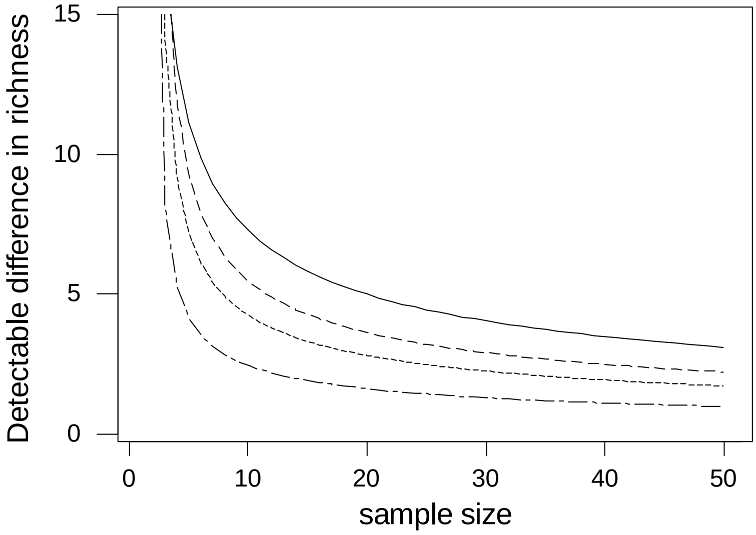

Figure 6. Detection differences in species richness for various sample sizes based on two sample t-tests (repeat random quadrats, solid line) and for paired t-tests (permanent quadrats) where correlation between time points equals 0.5 (dashed line), 0.7 (dotted line) and 0.9 (dash-dot).

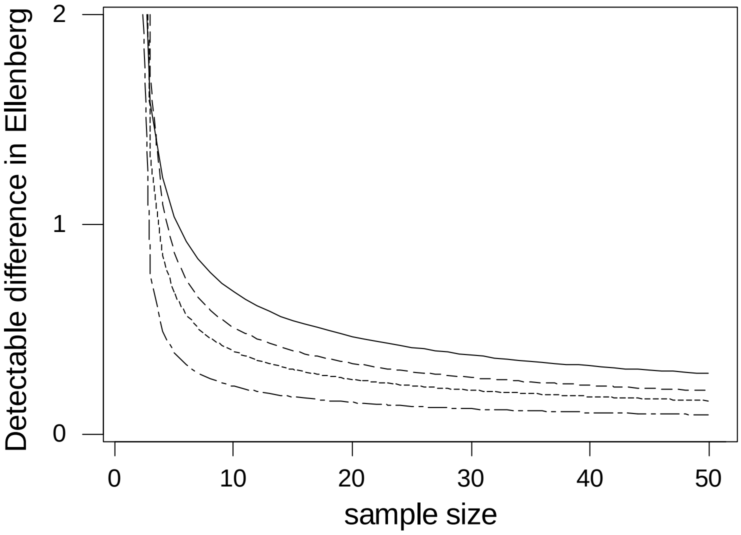

Figure 7. Detection differences in Ellenberg N for various sample sizes based on two sample t-tests (repeat random quadrats, solid line) and for paired t-tests (permanent quadrats) where correlation between time points equals 0.5 (dashed line), 0.7 (dotted line) and 0.9 (dash-dot).

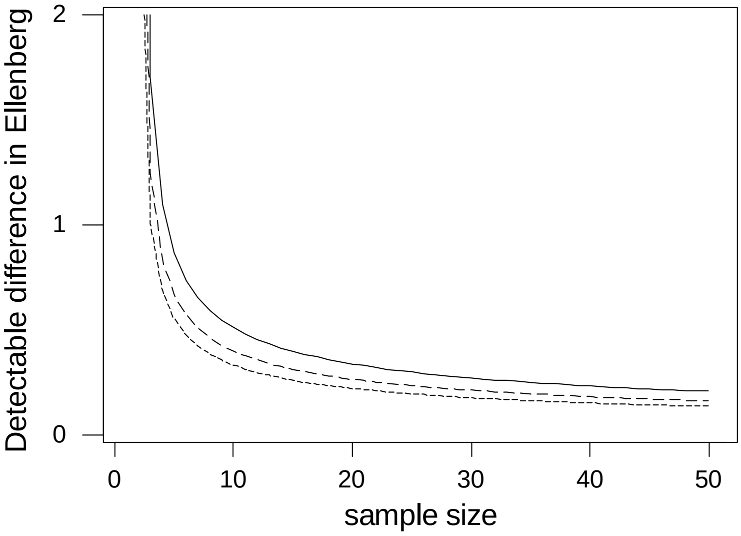

Figure 8. Detection differences in Ellenberg N for various sample sizes based on permanent quadrats with a autocorrelation of 0.5. The three curves represent power of 50% (lower), 65% (middle) and 85% (upper).

Figure 8 demonstrates the effect on detectability of reducing power using the British Ellenberg N mean sd as an example. For a sample size of 10 the 0.51 difference detectable at power of 85% is reduced to 0.33 at 50% power. However it is undesirable to reduce power to this level as half of the true differences would not be detected.

3.2.2 Repeated surveys from fixed units

In practice, data from repeat fixed point surveys were available and it was possible to examine how variable the community variables (species richness, British Ellenberg N, Nu and G scores) were over time. Appendices 1.12 and 1.13 summarise the correlations and standard deviations of the difference between repeat surveys for ESA quadrat data (4548 pairs) and ESA plot data (252 pairs) respectively. Once again these are summarised by categories where there are at least 20 pairs of values. The sd(diff) from ESA plots would appear to be lower than that from ESA quadrats. A further distillation of the data is given below where the correlation and sd(diff) is summarised across all the categories (Table 16 and Table 17). It is surprising that the correlations between repeat pairs can be negligible, even negative, in some instances but it should be remembered that these data contain repeats surveys from sites where the vegetation is undergoing change. Ideally these data would be restricted to sites which are considered to be stable as inclusion of other data will inflate the sd(diff), but in monitoring data sets the stability will inevitably vary from site to site.

Table 16. Summary of correlations for community variables across all categories.

	Mean corr	**Smallest corr**	**Largest corr**
Richness (n=71)	0.67	-0.01	0.94
Ellenberg N (n=71)	0.77	-0.05	0.98
Nu (n=116)	0.63	-0.20	0.94
G (n=116)	0.57	-0.01	0.94

Table 17. Summary of sd (diff) for community variables across all categories.

	Mean sd-diff	**Smallest sd-diff**	**Largest sd-diff**
Richness	3.79	1.20	7.68
Ellenberg N	0.30	0.06	0.92
Nu score	0.15	0.04	0.37
G score	0.14	0.03	0.39

Table 18. Detectable change at mean, minimum and maximum sd (diff) at a variety of sample sizes

	Species richness			**Ellenberg N**			**Nu score**			**G score**		
n	**mean**	**min**	**max**	**mean**	**min**	**max**	**mean**	**min**	**max**	**mean**	**min**	**max**
10	4.04	1.28	8.19	0.32	0.06	0.98	0.16	0.04	0.39	0.15	0.03	0.42
20	2.68	0.85	5.43	0.21	0.04	0.65	0.11	0.03	0.26	0.10	0.02	0.28
50	1.64	0.52	3.32	0.13	0.03	0.40	0.06	0.02	0.16	0.06	0.01	0.17
100	1.15	0.36	2.32	0.09	0.02	0.28	0.05	0.01	0.11	0.04	0.01	0.12
200	0.81	0.26	1.64	0.06	0.01	0.20	0.03	0.01	0.08	0.03	0.01	0.08

In Table 18 the change that can be detected at 85% power and at sample sizes of 10, 20, 50 100 and 200 has been calculated at mean, minimum and maximum sd (diff) as calculated across the category summaries in Appendices 1.12 and 1.13.

If permanent quadrats are to be used to monitor change in vegetation then it is useful to have data on the temporal variation in vegetation considered to be stable. If autocorrelation exists, and it is likely to, then permanent quadrats are more likely to detect change than random quadrats. In the examples used here a power of 85% has been employed. The appendices provide examples of the variation for different community variables in different categories and these can be used to interpolate in the graphs and tables to estimate the sample size necessary to detect change of a given magnitude.

4 PROVISIONAL TARGETS

4.1 METHODS

In this section, community variables calculated using the framework devised from the data classification (Section 2) were compared with community variables characterising sites known to be in favourable condition. This information was used in combination with the power testing results to calculate sample sizes required to be able to determine the change in attaining a favourable condition. This information has been used subsequently in the monitoring recommendations (Chapter 4).

Botanical data collected from quadrats located in pristine sites representing some Priority Habitats had previously been acquired from English Nature (Critchley *et al.* 1999; Fowbert & Critchley 2000). Community variables were calculated for these data sets. The variables were presence/absence weighted because of variations in the method of data collection and to enable comparisons to be made across the three AE data sets. The differences between a pristine target and an existing AE scheme sample were then calculated.

Community variables were also calculated for communities representing an endpoint for deterioration and a starting point for re-establishment of a Priority Habitat. For example, for the Lowland Calcareous Grassland Priority Habitat semi-improved MG6 grassland was used as a potential endpoint of deterioration, whilst MG1, MG6 and MG7 were used as potential starting points.

Graphs were drawn using the information in Table 17 and Table 18 from the power analysis. Figure 9 shows the linear relationships between detectable change and standard deviation at a range of sample sizes for Nu score. Equations for these lines were derived and used to calculate the actual detectable change at one of the sample sizes shown from the known standard deviations. Information for other sample sizes can be interpolated from Figure 9 and Figure 10. Figure 10 shows the relationship between sample size and detectable change at mean, minimum and maximum standard deviations (from Table 18).

The Upland Hay Meadow Priority Habitat had already been the subject of a power testing procedure (Fowbert *et al.* 2002) and the data from this were used in the monitoring schedule for that habitat.

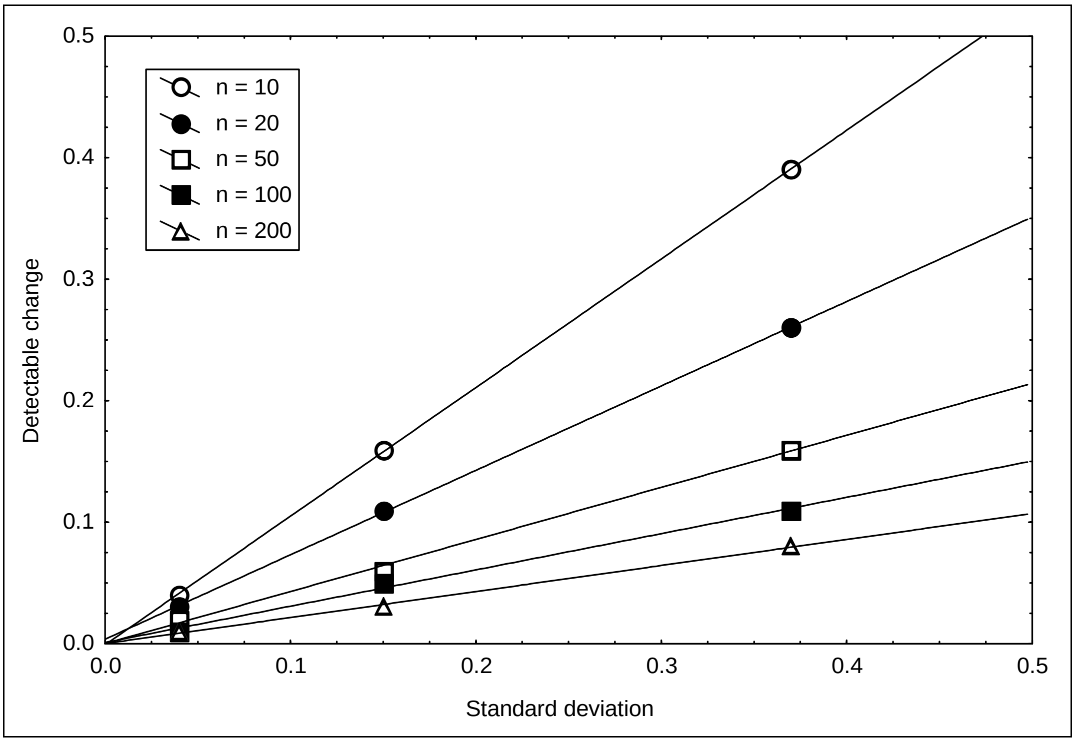

Figure 9. Relationship between standard deviation of differences and detectable change (at an 85% power) for Nu score at a range of sample sizes.

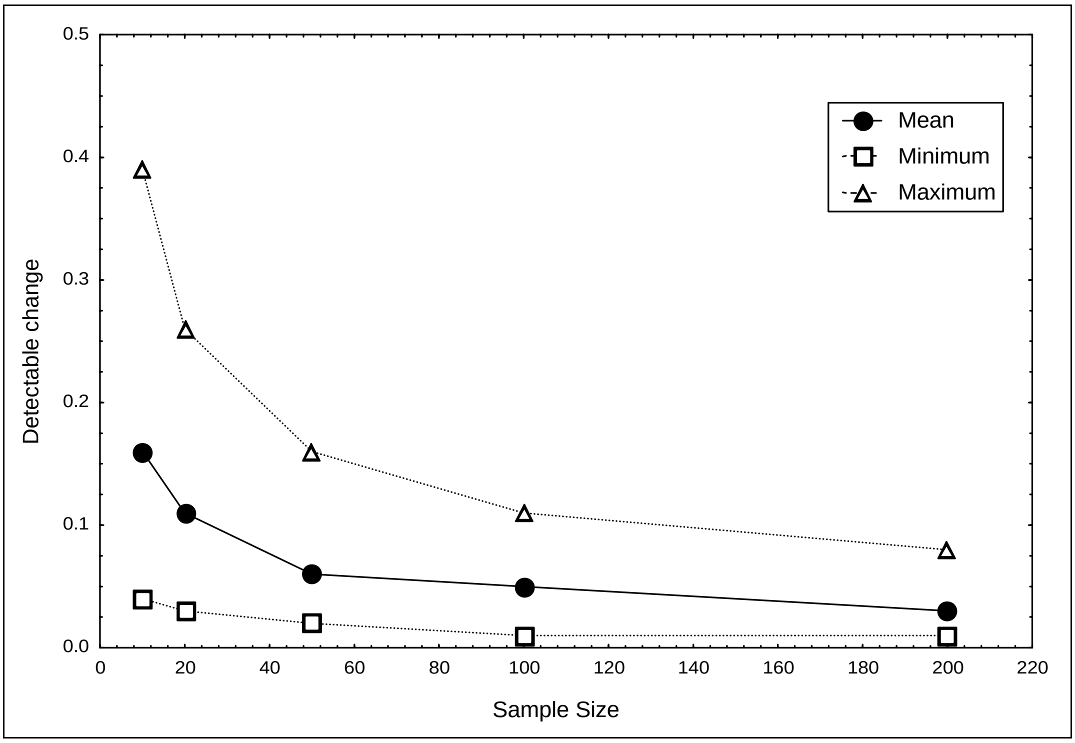

Figure 10. Relationship between detectable change and sample size at mean, minimum and maximum standard deviation of differences for Nu score.

4.2 RESULTS

In the following worked example the Nu score in the Priority Habitat Lowland Calcareous Grassland (LCG) is used. The mean scores together with the detectable change in those scores can be seen in Table 19. LCG in the South Wessex Downs ESA had an Nu score of –0.55 and, with a standard deviation of 0.11, a sample size of 100 is likely to be able to detect a change in the Nu score, if one occurs, of 0.03 (from Figure 9).

Table 19. Nu score (standard deviation in brackets) and detectable change at a variety of sample sizes for Lowland Calcareous Grassland. SD = South Downs, SX = South Wessex Downs, CH = Cotswold Hills.

			Sample Size				
Scheme/ESA	***n***	**Nu Score**	**10**	**20**	**50**	**100**	**200**
CSS	26	-0.34 (0.13)	0.14	0.09	0.05	0.04	0.01
SD Quadrats	49	-0.42 (0.12)	0.13	0.09	0.05	0.04	0.01
SX Plots	39	-0.55 (0.11)	0.12	0.08	0.05	0.03	0.01
CH Plots	13	-0.50 (0.19)	0.20	0.14	0.08	0.06	0.02
All	127	-0.45 (0.12)	0.13	0.09	0.05	0.04	0.01

Pristine CG2 had an Nu score of –0.68 and the differences between the pristine target and the samples from either CSS or the ESAs can be seen in Table 20. This table also shows the actual detectable change, which is the change that is likely to be detectable with the sample size *n* (from Figure 10). The percentage detectable change indicates that in the South Wessex Downs ESA, a change in the Nu score equivalent to 38% of the difference in the score between LCG in that ESA and pristine CG2 is detectable with a sample size of 39.

Table 20. Difference in score from target and the detectable changes in Nu score. ESA scheme codes as in Table 19.

Scheme/ESA	***n***	**Difference from CG2**	**Actual Detectable Change**	**% Detectable Change**
CSS	26	+0.34	0.08	24%
SD Quadrats	49	+0.26	0.05	19%
SX Plots	39	+0.13	0.05	38%
CH Plots	13	+0.18	0.18	100%
All	127	+0.23	0.03	13%

Table 21 shows sample sizes required to detect various levels of change based on the difference between pristine CG2 and LCG in the scheme/ESA. For the detection of a 100% difference in the South Wessex Downs ESA (*i.e.* 0.13, see Table 20), it is possible that a sample size of only 10 may be required (from Table 19). However, a 10% change (equivalent to 0.013) would need a sample size of 100-200 to be detectable.

Table 21. Required change (of the difference to CG2) and appropriate sample size. ESA scheme codes as in Table 19.

Change	**CSS**	**SD**	**SX**	**CH**	**All**
100%	<10	<10	<10	<10	<10
50%	<10	10	50-100	20-50	10-20
20%	20-50	20-50	100-200	100-200	50-100
10%	100-200	100	100-200	>200	100-200

These and similar calculations were carried out to provide information feeding into the future monitoring recommendations in Chapter 4. The same method can also be applied to other subsets of the AE monitoring data, using Figure 9 and Figure 10, or their equivalents for other community variables.