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CS2000 MODULE 10 – ENVIRONMENTAL CHANGE NETWORK LINK

Final Report

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Executive Summary

1. Module 10 of the Countryside Survey 2000 research programme addressed the issue of year-to-year variability in vegetation: whether it was likely to influence Countryside Survey results and how it might relate to weather patterns.

2. The vegetation of plots at Environmental Change Network (ECN) sites throughout the UK was recorded in 1998 and 1999. ECN is a collaborative, long-term monitoring programme, with the aim of detecting change in a wide range of environmental variables, using a series of intensively studied sites. For many of these plots, data were also available from 1997, 1996 and in some cases 1994. The data were analysed by testing for year-to-year differences in numbers of species and the ecological characteristics of those species (using the systems of Grime and Ellenberg); these variables have also been used in the analysis of the main CS2000 vegetation results. The Countryside Vegetation System (CVS) was used for classifying the vegetation and stratifying the sampling and analysis.

3. Year-to-year changes in CVS aggregate vegetation classes were found: 23% of the studied plots changed classification at some point. Between 1998 and 1999, the two years with the most data, 12% of plots changed. This compares with a change of 30% between 1990 and 1998 in CS2000 data.

4. Arable Crop/ Weed communities showed the largest year-to-year variability in species number and ecological characteristics; fertile grasslands and woodlands were also relatively variable.

5. The number of species per plot decreased significantly between 1997 and 1999, taking all vegetation classes together. The difference was also statistically significant in fertile grassland, lowland woodland and heath / bog classes when analysed separately. In the fertile grasslands, which showed the largest significant decrease, the decline in numbers of species was largely due to decreases in ruderal species ('weeds' able to grow quickly in temporary gaps in the grass sward). This may relate to the differences in weather between the dry conditions of 1995-7 and the substantially wetter period between 1997 and 1999.

6. In infertile grassland there were significant differences in some vegetation characteristics, but not species richness, between 1999 and earlier years; the tendency was away from stress tolerant plants and towards more fast-growing competitive ones. An increase in the mean Ellenberg fertility score in this vegetation class, indicated a higher proportion of species adapted to high nutrient conditions. This may reflect an ongoing change in response to nutrient enrichment (e.g. from atmospheric pollution and spray drift), detected in both CS1990 and CS2000 data.

7. Although there were significant differences between years, and climate may well have been an important factor causing these, very few significant correlations between vegetation and weather variables were found. This is probably because of the short length of the time series. Many climatic effects may be subject to a time-lag and interactions between variables.

8. An understanding of year-to-year changes in vegetation can help to inform the results of Countryside Surveys. Year to year variability can be large enough to obscure or distort long-term changes and should be accounted for in the interpretation of CS2000 and similar monitoring exercises. In the case of the CS2000 survey it is likely that changes of a similar nature would have

been detected if the main field survey were carried out in 1997 or 1999 rather than 1998; the size of the changes could however have been quite different.

9. We recommend that annual vegetation monitoring be continued at ECN sites with further developments to improve the coverage of vegetation types and sites. More detailed analysis, using other data from ECN sites should be carried out to improve understanding of the underlying mechanisms. Ultimately it should be possible to develop models of vegetation response to climate to help interpret results of wider, intermittent monitoring programmes.

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1. Introduction

Successive Countryside Surveys have carried out large-scale field surveys of British vegetation, using a stratified random sample of 1 km squares. The most recent survey, for Countryside Survey 2000 (CS2000) (Haines-Young *et al.*, 2000), was carried out in 1998-9 and can be compared with results from 1978 and 1990. Module 10 was designed to test whether year-to-year variations are likely to affect Countryside Survey results. To do this additional, annual, monitoring work was carried out at Environmental Change Network (ECN) sites, where detailed records of climate, vegetation and other variables are available and where land management is relatively stable. The stated aims of Module 10 were:

1. To repeat vegetation monitoring undertaken in 1997 at ECN sites in 1998 and 1999 using protocols compatible with CS2000.
2. To determine the relationship between annual fluctuations in vegetation at ECN sites and prevailing weather conditions.
3. To assess the extent to which vegetation monitoring in CS2000 is affected by year to year variations in weather.
4. To review the protocols for vegetation monitoring at ECN sites with respect to applications in Countryside Surveys and to make recommendations for the long-term adoption of such monitoring as a standard requirement for ECN sites.

An initial pilot study was carried out in the summer of 1997 funded by the DETR. This was essentially a repetition of a survey carried out using standard ECN methodology in 1996. The results are presented by Morecroft *et al.* (1997). In 1998 and 1999, two more surveys were carried out using the same plots and methodology. Additional plots were also set up to improve the coverage of different vegetation types, though linear features were not included in this contract.

Earlier studies have shown that at least some plant communities can change on a year-to-year basis, influenced by the weather. One of the best examples of this is a study of road verges at Bibury, Gloucestershire, which have been monitored since 1958. Dunnett *et al*. (1998) reported changes in the relative abundance of different functional types, correlated with various measures of climate. In general terms, stress tolerant and ruderal (weedy) species increased in response to warm, dry weather during spring and summer whereas competitive, fast-growing species increased after wet conditions. Other studies showing year-to-year changes that can be attributed to climate include those by Herben *et al.* (1995), Collins *et al*. (1987) and van der Maarel (1985). It is important to determine whether such effects are widespread and whether they can influence the variables used to interpret Countryside Survey results, most of which have relatively stable values, based on the presence or absence of species, rather than, for example, biomass or cover.

A number of measures of vegetation characteristics (subsequently termed 'vegetation indices') have been selected for use in interpreting results from the Countryside Surveys (Bunce *et al*., 1998; Firbank *et al.* 2000) and the same variables are used in the analyses reported here. They include number of species per plot and scores of functional attributes according to the systems of Grime and Ellenberg. Grime (1979) proposed that plant 'strategies' could be characterised in terms of a triangular scheme reflecting the degree to which any species is adapted to disturbance (removal of material) or 'stress' (lack of resources). Three primary strategies were identified: *competitors*, plants adapted to low levels of disturbance and stress, *ruderals* which are adapted to high levels of disturbance and *stress tolerators*, which are adapted to low levels of resources. There are numerous intermediates and it is possible to score species according to how close they are to each of the three primary strategies. This was done for a large number of species by Grime, Hodgson & Hunt (1988) and can be expressed as C-radius, S- radius and R- radius, so for example, the higher its C-radius, the more strongly a species exhibits the attributes of a competitor. The Ellenberg system deals with adaptations to particular environmental conditions and scores species 1-9 according to the habitats in which they are found, so for example a shade species would have a lower light (L) score than a species characteristic of open conditions. The system was original developed by Heinz Ellenberg for central Europe (e.g. Ellenberg, 1988), but has been adapted by Hill *et al.* (2000) to more accurately describe plant distributions in the British Isles. A shift in the mean value of CSR or Ellenberg scores should provide information on the nature of any change in the vegetation composition of different plots, sites or vegetation classes.

Data from the 1978 and 1990 Countryside Surveys were used to produce a statistical classification of vegetation, the Countryside Vegetation System (CVS) which has 100 classes of vegetation (Bunce *et al*, 1999). These vegetation classes are grouped together into eight aggregate classes (AC), which form one of the basic units for analysis of Countryside Survey results (Table 1.1). Aggregate vegetation classes formed the basis for our selection of plots at ECN sites and were the basic stratification in our analyses.

Table 1.1 Aggregate Vegetation Classes in the Countryside Vegetation System

I	Crops/weeds
II	Tall grass / herb
III	Fertile grassland
IV	Infertile grassland
V	Lowland wooded
VI	Upland wooded
VII	Moorland grass / mosaic
VIII	Heath / bog

2. Methods

Ten ECN sites (Fig. 1, Table 2.1) were used in this study, representing a wide range of vegetation types, climatic conditions and land uses. Between 11 and 23 plots were recorded at each site in 1999 and 1998 under this contract (Table 2.2). Plots were mostly selected from existing ECN 'fine grain' vegetation monitoring plots (Sykes & Lane, 1996) to allow the time series to be extended by including records from earlier surveys, in particular we have used data collected in the DETR funded pilot study in 1997 and from ECN recording in 1996. Three sites also had some records from 1994. Further selection was made on the basis of ensuring a good representation of different aggregate vegetation classes (Table 2.2) with the intention being to have at least 15 plots of each aggregate class across as many ECN sites as possible. To enable this, some plots that had previously received a less detailed 'baseline' survey (Sykes & Lane, 1996) were included in 1997 and 1998. In the case of Aggregate Class I, Crops/ Weeds, five completely new plots were set up at each of the four ECN sites with arable land (Drayton, Porton, Rothamsted and Wytham). The protocol for setting up these new plots is included in Appendix 1. Aggregate class II, Tall Grassland / Herb, was not sufficiently well represented amongst ECN plots to be thoroughly covered. This was anticipated, as it has the lowest area coverage of the Countryside Survey aggregate classes and occurs under land uses such as roadsides and field margins, which ECN monitoring was not designed to cover. Four plots from the 1997 survey were however kept within the recording programme and various other plots were classified as AC II in subsequent years. The final number of plots available for analysis was 158 (Appendix 4).

Table 2.1 ECN sites used in CS2000 Module 10

Site	Sponsor / operator (owner)	Main habitats
Alice Holt	Forestry Commission	Broad leaved plantation woodland
Drayton	MAFF / ADAS	Mixed farmland
Glensaugh	MLURI	Upland grassland
Hillsborough	DARD	Fertile pasture with some woodland
Moorhouse-Upper Teesdale	NERC/ CEH (English Nature)	Upland grassland and blanket bog
North Wyke	BBSRC/ IGER	Fertile pasture with some woodland
Porton	MOD/ DERA	calcareous grassland with some woodland
Rothamsted	BBSRC/ IACR	Arable farmland with some woodland
Sourhope	MLURI	Upland grassland
Wytham	NERC / CEH (Oxford Univ.)	Mixed broad-leaved woodland and mixed farmland

Figure 2.1 ECN sites used in CS2000 Module 10

Table 2.2 Location and vegetation type of plots recorded in 1998 and 1999 in CS2000 Module 10

Aggregate vegetation class	Alice Holt	Drayton	Glensaugh	Hillsborough	Moor House & Upper Teesdale	North Wyke	Porton	Rothamsted	Sourhope	Wytham	**Plots**	**Sites**[1]
I Crops/weeds		5					5	5		5	**20**	**4**
(II Tall grass / herb)				1			1	2			4	3
III Fertile grassland		12	1	3		3				3	**22**	**5**
IV Infertile grassland	1		3		1	3	10		1	3	**22**	**7**
V Lowland wooded	6			6		4	2	8		6	**32**	**6**
VI Upland wooded	8			2	4	2			1		**17**	**5**
VII Moorland grass / mosaic	1		3		10				7		**21**	**4**
VIII Heath / bog			7		8				2		**17**	**3**
All classes	**16**	**17**	**14**	**12**	**23**	**12**	**18**	**15**	**11**	**17**	**155**	

[1] Moor House and Upper Teesdale is a large site comprising two nature reserves, if the two reserves are considered as 2 sites, classes VI, VII, VIII are represented at 6, 5 & 4 sites respectively.

The basic method used was the ECN 'fine grain' vegetation monitoring method in which the presence of species is recorded in 10 randomly distributed 400 x 400 mm quadrats ('cells') within a larger 10 m x 10 m square plot. Plots and cells are permanently marked to ensure accurate relocation. The detailed methodology is described by Sykes & Lane (1996) and a comparison of the ECN and Countryside Survey methods is given by Morecroft *et al.* (1997). The method does differ from that of CS2000, which is not ideal for making comparisons, but it was adopted as it allowed a longer run of data to be analysed. Countryside Survey vegetation recording is based on species lists with cover estimates for a range of permanent plots located within randomly selected 1 km squares. Full details may be found in, for example Barr *et al.* (1993), but the different types are summarised in Appendix 2.

It is possible that Countryside Survey main plots are more stable than ECN fine grain plots as they cover a larger ground area and so are less likely to be influenced by very localised changes: ECN fine grain plots cover 1.6 m^2 randomly taken over 100 m^2 whereas Countryside Survey main (X) plots cover 200 m^2. Habitat (Y) plots cover 4 m^2 and linear ones 10 m^2 so are more likely to show a similar degree of variability to ECN fine grain plots. Table 2.3 shows the number of CS2000 plots changing classification for different plot types. This shows that the main (X) plots were more stable in classification than smaller ones over the longer course of time, but the differences were not large. This suggests that the ECN plots can be taken to give reasonable indication of the extent to which interannual variability affects vegetation classification in all CS2000 data.

Table 2.3 Percentage of CS2000 plots changing aggregate vegetation class between 1990 and 1998 for different plot types.

Main plots	24.5%
Habitat plots	30.4%
Boundary plots	35.4%
Hedgerow plots	32.1%
Road verge plots	33.5%
Streamside plots	26.6%

The field surveys were carried out between mid June and the end of August in 1998 and 1999 (in some of the early surveys, recording continued into early September). As far as possible the same surveyors were used in each year at each site. The surveyors used are listed in Appendix 3. During the 1999 survey our main surveyors, D. McCutcheon and P. Wilson both recorded the same plots at two of the more diverse sites - Moorhouse / Upper Teesdale and Porton Down. Good comparability was found for 'Category 1' species (see below). Quality control exercises were also carried out in 1996 and 1997. Staff at each ECN site were responsible for marking plots and facilitating the surveyors' visits.

The analysis only included species used in the analysis of Countryside Survey results (Category 1 species) and likewise counted variable and taxonomically disputed species such as bramble (*Rubus fruticosus* agg.) as a single species.

We have tested for changes in the aggregate vegetation class between years and also for the following vegetation indices, which are also included in the analysis of the main CS2000 results:
1. Number of species
2. Mean C radius

3. Mean S radius
4. Mean R radius
5. Mean Ellenberg R score (pH range)
6. Mean Ellenberg N score (soil fertility)
7. Mean Ellenberg W score (soil moisture)
8. Mean Ellenberg L score (light)

3 Results

3.1 Changes between aggregate vegetation class

36 (23%) of the 158 plots changed aggregate vegetation class, 15 (9%) more than once (Appendix 5). Table 3.1 summarises which changes between classes took place. The changes between classes are not random, but tend to occur between similar aggregate classes. The largest number of changes were losses from upland wooded (AC VI) to lowland wooded (AC V) and moorland grass / mosaic (AC VII) and from fertile grassland (AC III) to tall herb / grass (AC II).

Table 3.1 Summary of changes in plot classifications between different aggregate vegetation classes

	New Aggregate Class									
Initial Aggregate Class	**0**	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**All**
I Crops/weeds	1		2	2						5
II Tall grass / herb				1	2	1	3			7
III Fertile grassland		2	5							7
IV Infertile grassland			3	1			2	2		8
V Lowland wooded			1				3			4
VI Upland wooded					2	6		6	1	15
VII Moorland grass / mosaic					4		2		2	8
VIII Heath / bog								3		3
All classes	1	2	11	4	8	7	10	11	3	57

3.2 Vegetation indices: General considerations

We have analysed pair-wise combinations of all years for all vegetation indices to test for significant differences. In addition to using data for all plots combined, we have also analysed data for each site and each vegetation class separately, to test whether different processes are operating in different vegetation types or geographical areas. This has produced a large number of comparisons and interpretation needs to take into account the dangers associated with multiple comparisons in that some apparently significant results would be expected by chance alone. As there are approximately 140 site- or vegetation class- specific comparisons for each vegetation index, approximately 7 significant results (at the 0.05 level) would be expected for each vegetation index by chance alone. All of the indicators, except the Ellenberg R and W values, show considerably more significant results than this and we can have confidence that there are real year to year differences. The data presented are from all plots possible for each comparison. This means that there are more data for 1998 - 1999 comparisons than in earlier years, however the findings are not greatly changed by restricting analysis to plots with 4 years' data.

Species number showed the highest year to year variability of the indices, having a coefficient of variation of 16% compared to 7-9% for CSR radii and 2-4% for Ellenberg indices (Table 3.2). Crops/ Weeds (AC I) show the largest year to year variation in species number and CSR radii, followed by fertile grasslands (AC III), and lowland and upland woodlands (AC V & VI respectively); the other aggregate classes are more stable.

Table 3.2 Coefficients of variation (mean / standard deviation) for different vegetation indices and different vegetation classes

Aggregate Class	Number of species	C radius	S radius	R radius	Ellenberg R	Ellenberg N	Ellenberg W	Ellenberg L
I Crops /weeds	61.9	25.3	11.5	12.3	3.5	3.1	3.1	2.7
II Tall grass / herb	14.9	4.5	9.2	5.4	2.4	3.3	2.8	1.7
III Fertile grassland	24.8	11.6	9.7	8.1	2.7	3.3	2.9	1.8
IV Infertile grassland	11.3	5	4.4	5	2.3	3.9	2.2	1.2
V Lowland wooded	20.6	8.6	9.9	13.5	4.1	4.2	3.1	4.7
VI Upland wooded	17	9.3	9.1	8.7	5.5	4.9	2	2.4
VII Moorland grass / mosaic	9.9	4.6	4.3	6.6	3.7	5.1	2.5	1
VIII Heath / bog	11.5	4.5	2.9	2.9	4.5	3.4	2	1.6
All classes	15.9	8.3	6.7	8.4	3.5	3.9	2.6	2.2

3.3 Species number

Taking all sites and vegetation types together, for the period 1996 - 1999, the mean number of species per plot peaked in 1997 with a mean value of 11.5 (Fig. 3.1) and was lowest in 1999 with a mean of 10.0 species per plot. A similar pattern was seen at most sites individually. Statistical analysis of the changes within plots (Mann Whitney U tests or t tests according to whether distributions were normal or not) showed that taking all plots together there were significantly ($p<0.05$) fewer species per plot in 1999 compared to 1996, 1997 or 1998 (Table 3.3). The particularly large difference between 1999 and 1997 was significant at the $P<0.001$ level. Looking at sites individually, 7 of the 10 sites showed at least one significant difference between years (Table 3.3). Moor House / Upper Teesdale was unusual in that it exhibited the reverse pattern to the overall one, however none of the differences between years were significant (Table 3.3). In the three sites with data from 1994 it can be seen that species numbers were intermediate between the subsequent maxima and minima.

Taking the aggregate classes separately (Fig. 3.2; Table 3.4), most classes show the general pattern of a minimum in 1999 and to a lesser extent a maximum in 1997, but significant ($p < 0.05$) differences were only found in fertile grassland (AC III), lowland wooded (AC V) classes (Table 3.4; Fig. 3.3) and, in one case (1997-99), heath / bog (AC VIII).

Similar analysis were performed on all the vegetation indices, but to keep this report concise, only summary graphs of the type presented in Fig. 3.3 are presented for the other variables. (n.b. because the statistical analysis is based on changes within individual plots rather than differences in overall mean numbers - which also vary according to which plots were included in each year - the differences in Fig. 3.3 do not always match up with those implied by Fig. 3.2).

Fig. 3.1 Mean number of species per plot in successive years across sites.

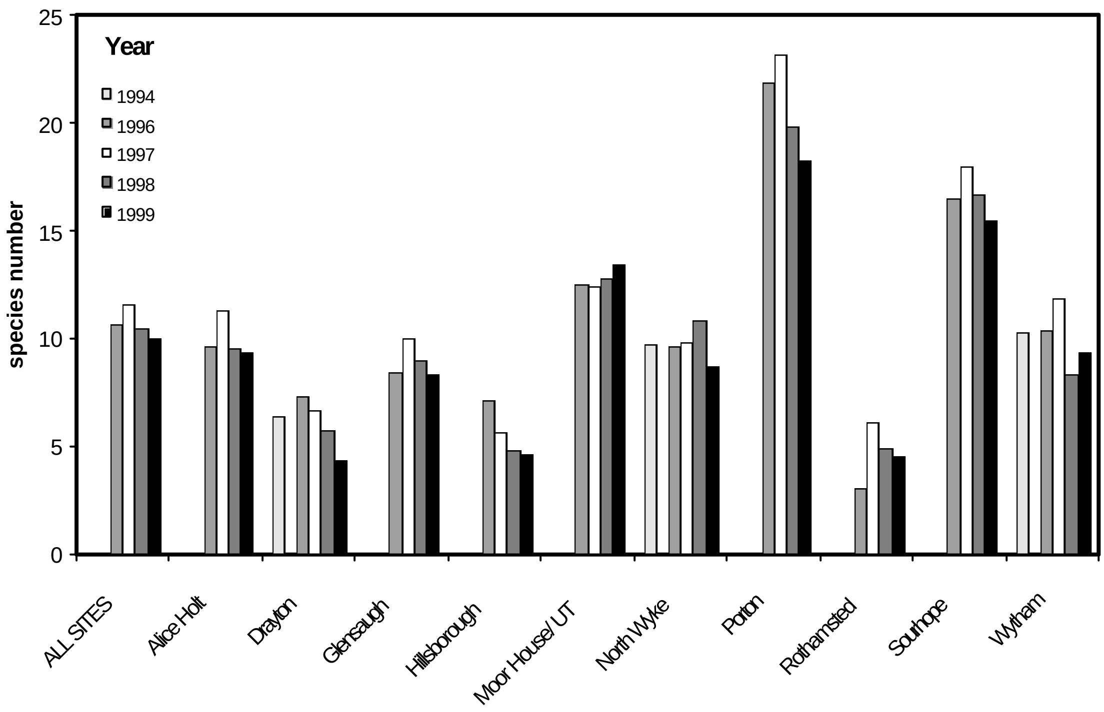


Fig. 3.2 Mean number of species per plot in successive years across vegetation classes

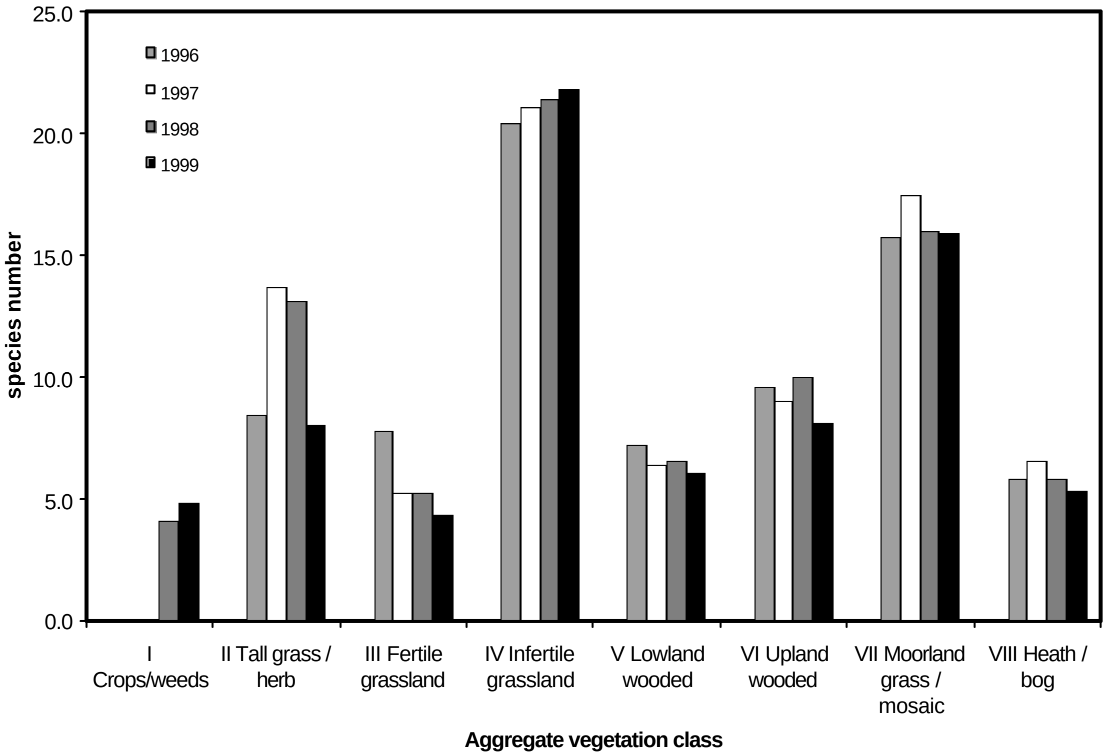


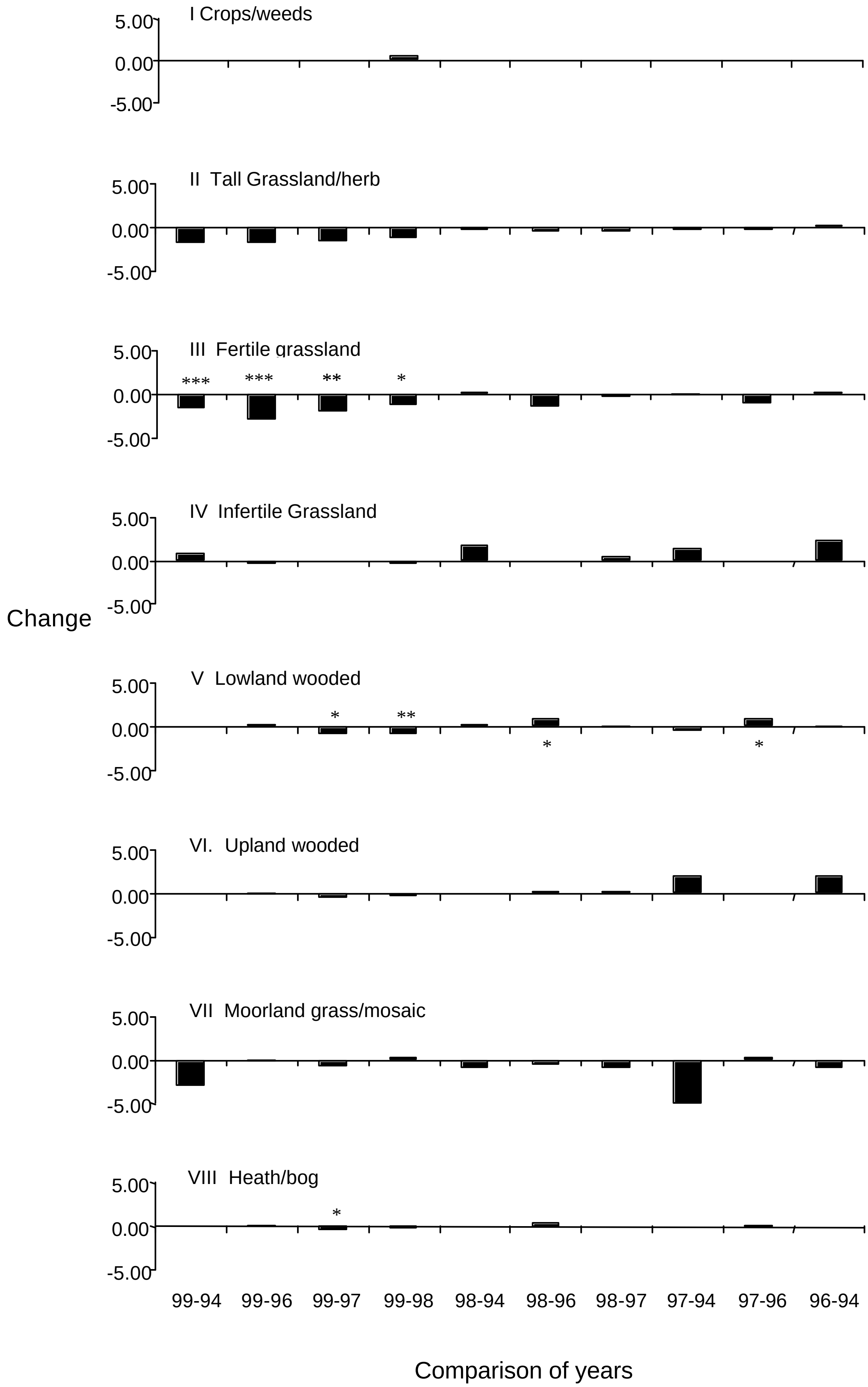
Table 3.3 Year to year comparisons of number of species per plot, by site. Here and elsewhere asterisks indicate the degree of significance: * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$. (because the statistical analysis is based on changes within individual plots rather than differences in overall means - which also vary according to which plots were included in each year - the differences in Fig. 3.3 do not always match up with those implied by Fig. 3.2).

	Comparison	Alice Holt	Drayton	Glensaugh	Hillsborough	Moor House & U. Teesdale	North Wyke	Porton	Rothamsted	Sourhope	Wytham	All Sites
Mean Change	99-94		-1.75				-1.33				0.23	-0.84
	99-96	0.29	-2.75	-0.07	-2.25	-0.20	-2.08	2.40	0.90	-1.36	0.08	-0.51
	99-97	-0.33	-1.80	-1.70	-1.40	0.14	0.00	1.10	-2.20	-1.50	-0.82	-0.82
	99-98	-0.50	-1.31	-0.64	-0.25	0.60	-1.45	-0.88	-0.40	-1.18	0.33	-0.45
	98-94		0.00				-0.17				1.20	0.39
	98-96	0.53	-1.00	0.57	-2.00	-0.80	-0.82	2.10	2.50	-0.18	0.60	0.01
	98-97	-0.30	0.10	-0.40	-1.20	-0.43	1.50	0.80	-0.60	-0.20	-0.40	-0.13
	97-94		-0.10				-2.00				1.00	0.00
	97-96	0.70	-1.10	0.80	-0.70	-0.36	-2.30	1.30	3.10	0.00	0.73	0.20
	96-94		1.00				0.38				0.15	0.50
Standard deviation of mean change	99-94		1.60				1.63				2.95	2.40
	99-96	2.27	2.05	2.70	3.57	3.35	2.31	2.88	1.37	2.50	1.98	2.93
	99-97	3.24	2.04	2.06	2.12	1.99	1.89	2.81	2.04	1.84	1.94	2.34
	99-98	1.83	2.63	1.82	2.01	2.14	1.44	4.08	2.90	2.18	3.48	2.62
	98-94		1.71				1.33				2.70	2.08
	98-96	2.95	1.54	2.44	4.61	2.84	2.75	2.13	1.58	1.40	2.07	2.86
	98-97	3.56	3.35	1.90	2.25	3.01	1.90	3.05	2.01	1.81	1.65	2.55
	97-94		3.03				2.00				3.44	3.15
	97-96	2.11	2.64	1.48	3.06	2.59	2.58	2.21	1.52	2.00	2.76	2.65
	96-94		1.41				2.29				2.38	2.06
Number of plots	99-94	0	12	0	0	0	6	0	0	0	13	31
	99-96	14	12	14	12	25	12	10	10	11	13	133
	99-97	9	10	10	10	14	10	10	10	10	11	104
	99-98	14	13	14	12	25	11	16	15	11	15	146
	98-94	0	12	0	0	0	6	0	0	0	10	28
	98-96	15	12	14	12	25	11	10	10	11	10	130
	98-97	10	10	10	10	14	10	10	10	10	10	104
	97-94	0	10	0	0	0	5	0	0	0	11	26
	97-96	10	10	10	10	14	10	10	10	10	11	105
	96-94	0	12	0	0	0	13	0	0	0	13	38
Significance of results	99-94		**									
	99-96		***		*		**	*				*
	99-97		*	*					**	*		***
	99-98						**					*
	98-94											
	98-96		*					*	***			
	98-97						*					
	97-94											
	97-96						*		***			
	96-94		*									

Table 3.4 Year to year comparisons of number of species per plot, by aggregate vegetation class

	Comparison	I Crops/weeds	II Tall grassland/herb	III Fertile Grassland	IV Infertile Grassland	V Lowland wooded	VI Upland wooded	VII Moorland grass/mosaic	VIII Heath/bog	All Classes
Mean Change	99-94		-1.75	-1.62	0.80	0.14	0.00	-3.00		-0.84
	99-96		-1.86	-3.00	-0.48	0.24	-0.13	-0.28	0.06	-0.51
	99-97		-1.57	-2.00	-0.16	-0.86	-0.50	-0.78	-0.50	-0.82
	99-98	0.54	-1.33	-1.29	-0.39	-0.93	-0.40	0.24	-0.29	-0.45
	98-94		-0.33	0.23	1.80	0.20	0.00	-1.00		0.39
	98-96		-0.50	-1.53	-0.05	1.00	0.27	-0.52	0.35	0.01
	98-97		-0.50	-0.27	0.47	-0.07	0.20	-0.89	0.00	-0.13
	97-94		-0.25	-0.10	1.40	-0.40	2.00	-5.00		0.00
	97-96		-0.29	-1.09	0.00	1.00	0.00	0.22	0.10	0.20
	96-94		0.25	0.21	2.33	-0.14	2.00	-1.00		0.50
Standard deviation of mean change	99-94		2.99	1.26	4.32	1.57				2.40
	99-96		3.39	2.45	4.40	1.66	2.77	3.03	1.68	2.93
	99-97		1.90	2.05	2.91	2.17	3.06	2.39	0.71	2.34
	99-98	5.64	1.75	1.96	3.00	1.72	1.99	2.37	0.99	2.62
	98-94		0.58	1.64	3.96	1.30				2.08
	98-96		3.94	2.95	4.32	2.25	2.69	2.29	1.22	2.86
	98-97		3.15	3.41	2.63	2.50	2.04	2.83	0.67	2.55
	97-94		4.65	2.56	4.51	0.89				3.15
	97-96		3.20	2.81	3.92	2.10	2.58	2.07	1.10	2.65
	96-94		2.22	1.75	3.01	1.46				2.06
Number of plots	99-94	0	4	13	5	7	1	1	0	31
	99-96	0	7	15	21	33	15	25	17	133
	99-97	0	7	11	19	29	10	18	10	104
	99-98	13	6	17	23	30	15	25	17	146
	98-94	0	3	13	5	5	1	1	0	28
	98-96	0	6	15	21	31	15	25	17	130
	98-97	0	6	11	19	30	10	18	10	104
	97-94	0	4	10	5	5	1	1	0	26
	97-96	0	7	11	19	30	10	18	10	105
	96-94	0	4	19	6	7	1	1	0	38
Significance of results	99-94			***						
	99-96			***						*
	99-97			**		*			*	***
	99-98			*		**				*
	98-94									
	98-96					*				
	98-97									
	97-94									
	97-96					*				
	96-94		*							

Fig. 3.3 Changes in number of species per plot in comparisons of different pairs of years



3.4 Plant strategies

There were a variety of significant ($p < 0.05$) changes in the mean C-, S- and R- radii at different sites and in different vegetation types. Some of the significant relationships are probably one - off phenomena that are hard to generalise about, but patterns can be discerned in the data.

One of the most interesting features is that in fertile grasslands (AC III), R- radius was lower in 1999 than in other years, whereas in 1998 it was higher (Fig. 3.6). In contrast C- radius (Fig. 3.4) showed the opposite trend, being higher in 1999 and lower in 1998. This suggests a decline in ruderals and / or an increase in competitors between 1998 and 1999. In view of the overall lower numbers of species in 1999 (Fig 3.2), a net loss of ruderals is most likely. There was also a significant increase in S radius (Fig. 3.5) in fertile grasslands between 1998 and 1999, which could also have resulted from a decline in ruderals. This phenomenon was one of the clearest trends in the analysis, so we examined it further by looking at changes in individual species in the ten plots of AC III which were recorded in all years. Table 3.5 shows the results. Whilst there was a diversity of responses there was indeed a group of ruderal species, including for example *Cerastium fontanum* (common mouse ear) and *Sonchus asper* (prickly sow thistle), which were only recorded in the period 1996 - 1998 and were absent in 1999. There were also low numbers of the most common ruderals, *Poa annua* (annual meadow grass) and *Stellaria media* (common chickweed) in 1999. In contrast the most common of the agricultural grasses, *Lolium perenne* (perennial rye grass) was consistently present and the second most common in this dataset, *Poa trivialis* (rough meadow grass), showed a small decline in 1997 and 1998. Although there is a relative shift from R to C strategies between 1998 and 1999, it should be noted that under the terms of the definitions of Grime et al (1988) the most dominant grasses in this habitat actually show elements of all three primary strategies.

Infertile grasslands (IV) showed a significant increase in mean C radius (Fig. 3.4) in 1999 compared to 1998 and 1996 and significant decrease in S radius (Fig. 3.5) in 1999 compared to 1998 and 1997, which implies a shift in composition away from stress tolerators towards competitors; there was no significant difference in R- radius (Fig. 3.6).

Fig. 3.4 Comparison of mean C- radius in different pairs of years across vegetation types

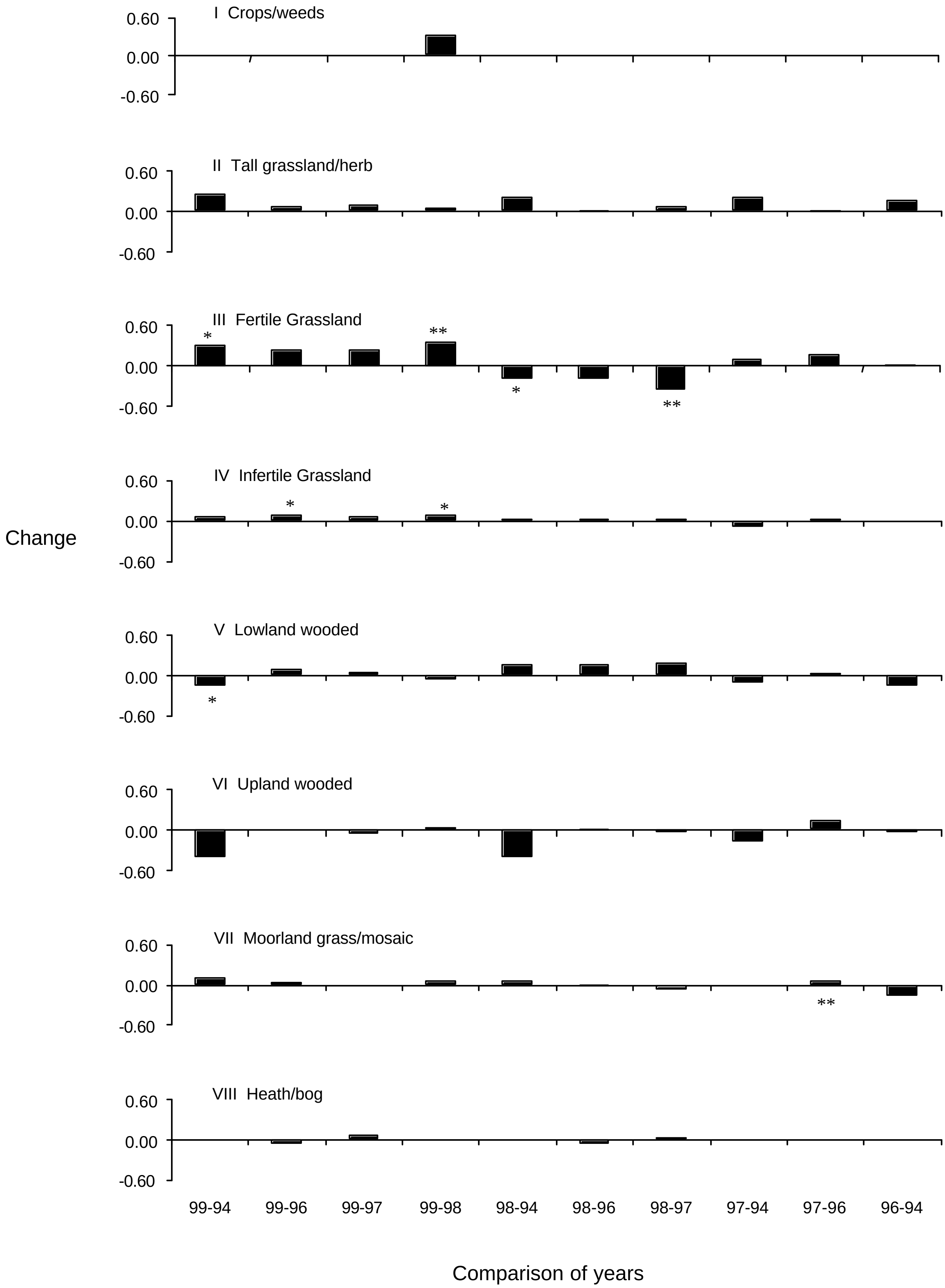


Fig. 3.5 Comparison of mean S- radius in different pairs of years across vegetation types

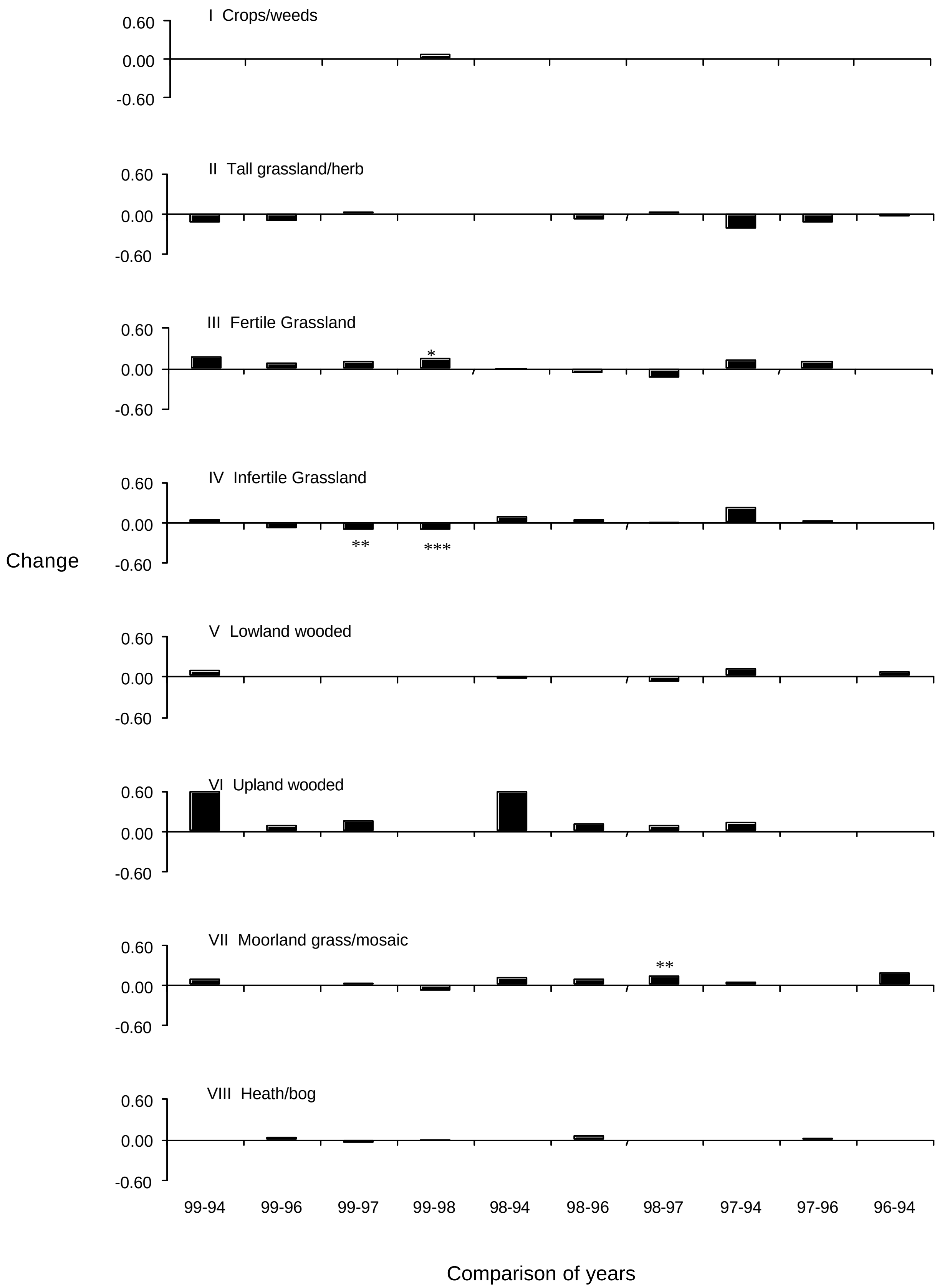


Fig. 3.6 Comparison of mean R- radius in different pairs of years across vegetation types

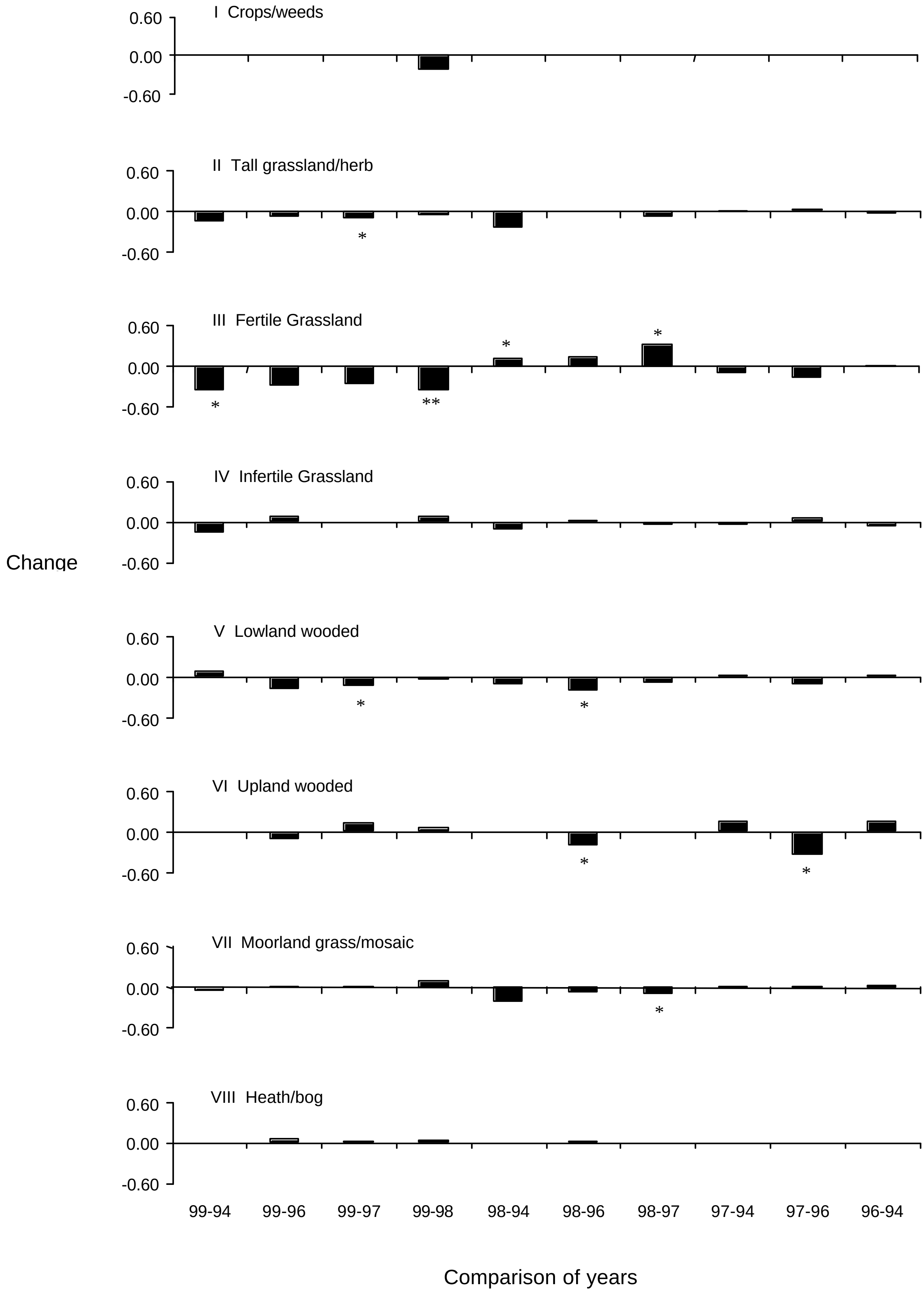


Table 3.5 Species in Fertile Grassland (AC III) plots for which records are available for all years, ranked by decreasing R- radius, indicating decreasing ruderal character. The CSR strategy (Grime 1988) is indicated the C- S- and R- radii (c-rad etc.)

	Species	C-rad	S-rad	R-rad	survey year				
					1994	1996	1997	1998	1999
species showing ruderal characteristics	Capsella bursa-pastoris	1	1	5	1	1		2	
	Poa annua	1	1	5	8	8	5	8	3
	Stellaria media	1	1	5	4	8	5	7	1
	Bromus hordeaceus	2	1	4				1	
	Cerastium fontanum	2	2	4		1		1	
	Leontodon autumnalis	2	2	4			1		
	Rumex crispus	2	1	4			1		
	Sonchus asper	2	1	4		1	1		
	Sonchus oleraceus	2	1	4				1	
	Geranium dissectum	1	2	4			1		
Intermediate species	Agrostis capillaris	3	3	3				1	
	Agrostis stolonifera	3	1	3	7	5	5	2	1
	Cirsium vulgare	3	1	3			1	1	
	Festuca pratensis	3	3	3	1				
	Holcus lanatus	3	3	3	1				
	Lolium perenne	3	2	3	10	10	10	10	10
	Lysimachia nummularia	3	3	3			1		
	Poa pratensis	3	3	3	1	3	3	2	
	Poa trivialis	3	2	3	9	9	7	8	9
	Ranunculus repens	3	1	3				2	
	Veronica arvensis	1	3	3				1	1
lacking ruderal charact-eristics	Alopecurus pratensis	4	2	2		1			
	Dactylis glomerata	4	2	2	1	1	1	1	1
	Urtica dioica	5	1	1			1		
	Mean number of species				**4.9**	**5.6**	**4.8**	**5.1**	**3**

3.5 Ellenberg values

Although the magnitude of changes in the Ellenberg number was small, there were some significant differences, especially for fertility (N) and light (L) values. The mean L value of fertile grasslands (AC III) was significantly higher in 1999 than all other years (Fig. 3.7), indicating a lower degree of shade tolerance. This is presumably linked to the increasing C radius and decreasing R-radius reported above. It is possible that some of the ruderal species that were eliminated between 1998 and 1999 had a higher shade tolerance than the agricultural grasses, which dominated these plant communities. It would be unwise to read too much into this as the absolute L values remain typical of open rather than shady communities and there is little scope for change in this, given that in these grasslands sward height is kept low by grazing and cutting. Some trends in L values also occurred in the lowland wooded class, with 1999 significantly lower than 1997 and 1998; 1998 was also lower than 1997. This is consistent with canopy closure causing more light demanding species to be shaded out. This would be consistent with a recovery phase after thinning in woodlands; however site specific data do not appear to be consistent with this. For example the non-intervention woodlands at Rothamsted show this trend as much as the more actively managed woodland at Alice Holt; Wytham which has a mixture of managed and unmanaged plots shows the reverse trend. As with the grasslands, the absolute values are small and it would be unwise to read too much into the data.

N values in infertile grasslands (IV) were significantly higher in 1999 than in 1996, 97 and 98 (Fig. 3.8). This is likely to reflect the trend in CSR strategies towards C selected species and away from S selected species. Competitors in the CSR scheme generally have a high capacity to take advantage of high nutrient supplies and grow quickly, whereas stress tolerators are slower growing and less responsive to nutrients.

Ellenberg R and W scores (Figs. 3.9 and 3.10) showed few significant differences between years and no clear patterns emerged.

Fig. 3.7 Changes in Ellenberg L in comparisons of different pairs of years

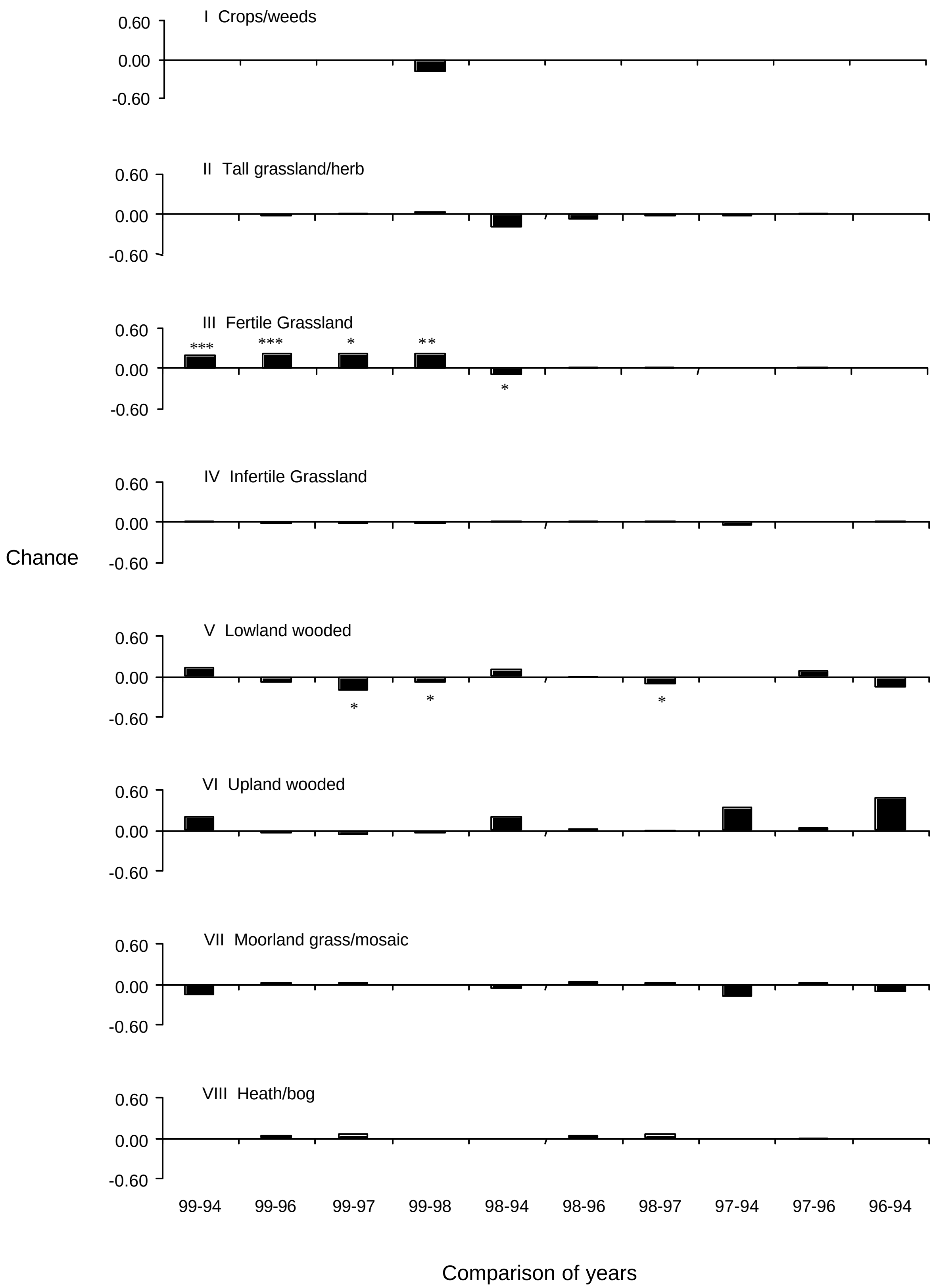


Fig. 3.8 Changes in Ellenberg N in comparisons of different pairs of years

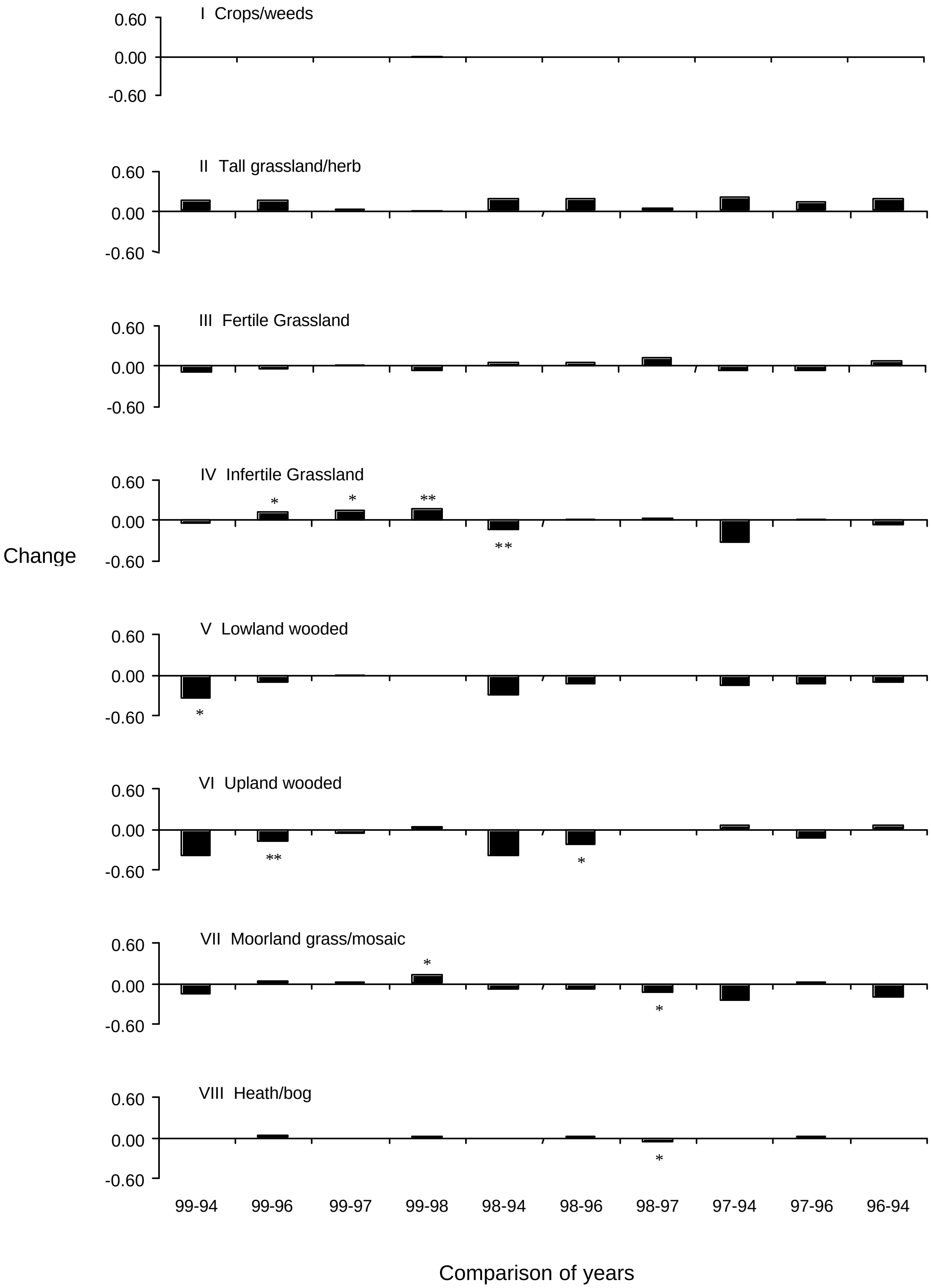


Fig. 3.9 Changes in Ellenberg R in comparisons of different pairs of years

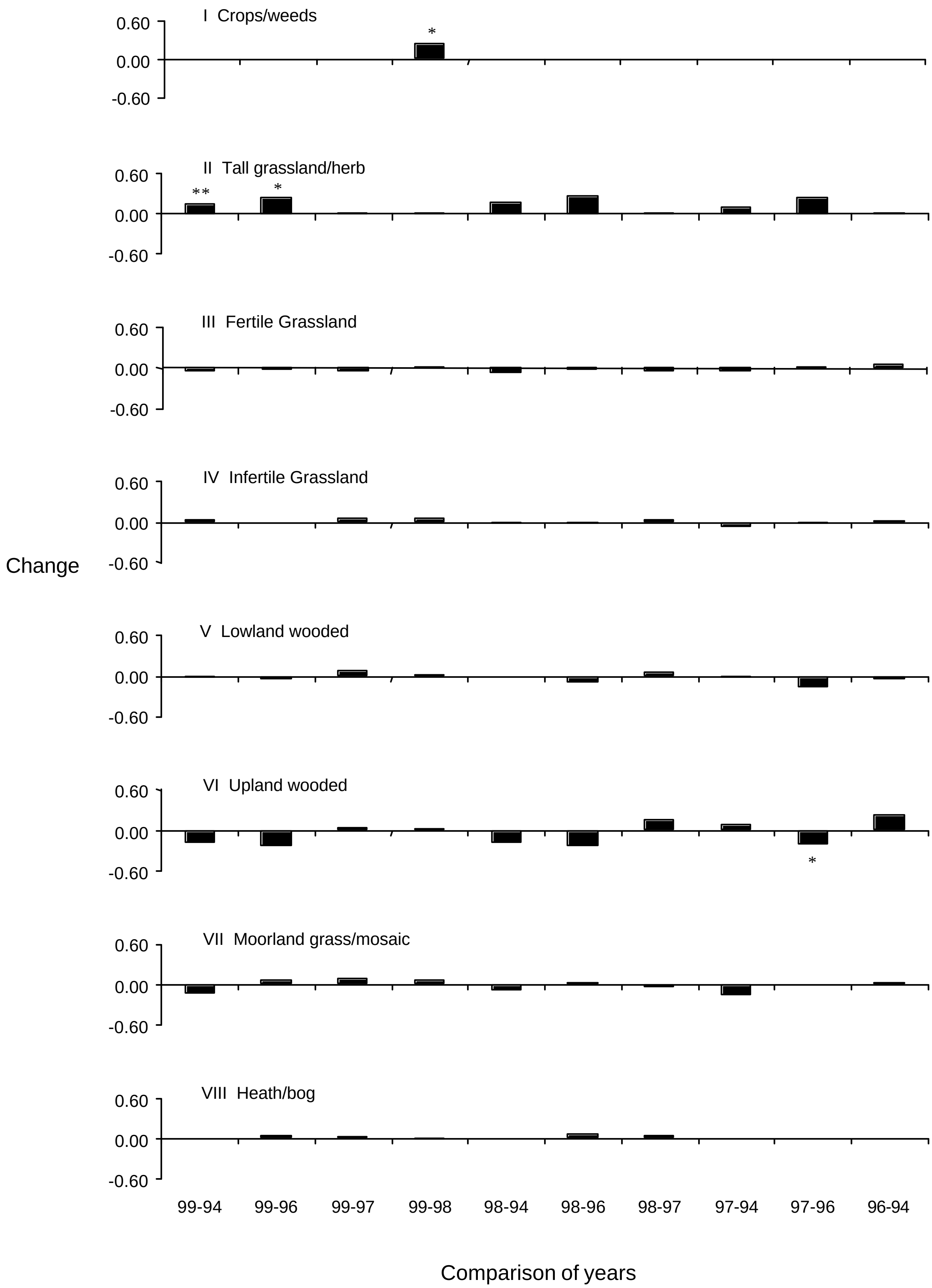
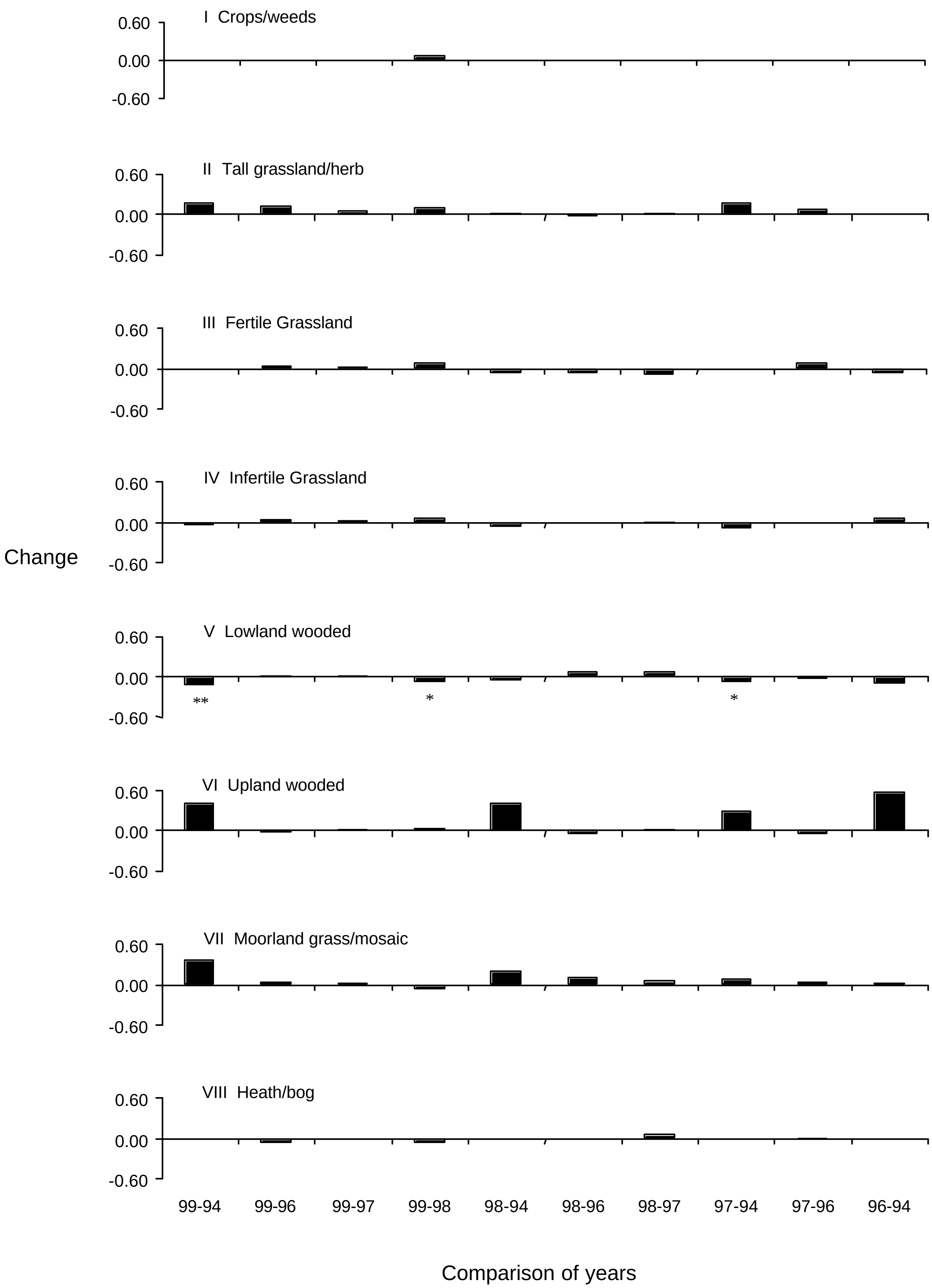


Fig. 3.10 Changes in Ellenberg W in comparisons of different pairs of years



3.6 Relationships with Climate

Five climatic variables were studied: mean temperature, mean maximum temperature, mean minimum temperature, mean 100 mm soil temperature and total precipitation. All of these variables can influence plant growth, reproduction and germination and are hypothetical explanations for the year to year differences in vegetation. Data were amalgamated into quarterly and yearly means or totals, to test the role of timing and duration of climatic conditions. For each vegetation index, relationships were examined with the climatic variables for (1) each of the five quarters up to and including the summer of the survey and for (2) the year ending with the *summer* of the survey and (3) the year ending with the *spring* of the survey year. The results for correlations with yearly data are shown in Table 3.6. One example of the correlations of a vegetation index, Ellenberg R values, with quarterly climate data is given in Table 3.7 and the complete set of correlations for quarterly climate means is given in Appendix 6.

In all there were 35 different climatic variables, analysed for each of the eight vegetation indices and for each aggregate class and for all classes combined, giving a total of 35*8*9 = 2520 tests/correlations. As in the previous sections it is important to be wary of the dangers of attaching too much importance to any single relationship, given so many comparisons. The total number of significant ($p<0.05$) results obtained was 90, well below the 126 (5%) that would be expected by chance alone (if the climate measurements were independent). This suggests that *these* climate variables are unlikely to explain all the year to year differences in reported in the previous section. The fact that climate measurements are not independent (e.g. maximum and minimum temperatures contribute to mean temperature), makes this all the more unlikely, as we would expect to see clusters of significant relationships with slightly different correlation coefficients.

A few clusters of significant relationships can be discerned in data and these may reflect real correlations, but the data do not generally provide an explanation for the year to year differences in vegetation reported above. Fertile grasslands (AC III) differed significantly, year-to-year, in species number, C- and R- radius and Ellenberg L values. However very few significant climatic relationships were found with these variables. Substantially more were found for Ellenberg R score and some of the yearly variables were significant for Ellenberg W and N scores. Infertile grasslands (AC IV) also showed very few significant climate relationships in those variables with significant year to year differences.

The R-radius of aggregate class VII (Moorland / grass mosaic) was one of the few instance of a consistent series of climate relationships. It was found to be significantly, negatively correlated with all measures of temperature (mean, maximum and minimum air temperature and mean soil temperature) in the autumn preceding the survey and also with the minimum temperature in both the summer of the survey and the preceding summer. It was also negatively correlated with rainfall in the spring preceding the survey. Curiously there was only one significant difference between years (1998 was lower than 1997) for R-radius in this vegetation class. Ellenberg W score in this vegetation class was also significantly correlated with temperature and maximum temperature in the year up to and including the summer of survey; it could also be related to rainfall in the year preceding the summer of survey.

Table 3.6 Correlation coefficients (r) between vegetation indices and aspects of climate in the preceding year - including and excluding the summer of survey. Significant (p<0.05) results are indicated by shading.

(a) Number of Species	aggregate class								
	I	II	III	IV	V	VI	VII	VIII	All
Temperature including summer of survey	-0.80	0.32	-0.07	0.49	0.18	0.52	0.23	0.07	-0.17
Temperature excluding summer of survey	-0.59	0.10	-0.02	0.18	0.25	0.04	0.29	0.18	0.21
100 mm soil temp. incl. summer of survey	-0.39	-0.14	0.07	0.38	0.05	0.12	0.27	0.04	-0.15
100 mm soil temp. excl. summer of survey	-0.17	-0.05	-0.27	0.03	0.34	0.18	0.39	0.12	-0.04
Mean maximum temp incl. summer of survey	-0.83	0.38	0.03	0.57	0.21	0.55	0.31	0.26	0.06
Mean maximum temp excl. summer of survey	-0.59	0.09	0.04	0.15	0.23	-0.05	0.27	0.29	0.32
Mean minimum temp incl. summer of survey	-0.69	0.22	-0.18	0.31	0.11	0.41	0.15	-0.13	-0.39
Mean minimum temp excl. summer of survey	-0.61	0.12	-0.13	0.21	0.25	0.28	0.25	-0.02	0.07
Rainfall incl. summer of survey	-0.07	-0.02	-0.01	-0.22	0.45	-0.39	-0.02	-0.17	-0.19
Rainfall excl. summer of survey	0.23	0.00	-0.01	-0.02	0.48	-0.19	0.21	0.03	-0.13

(b) C- radius	aggregate class								
	I	II	III	IV	V	VI	VII	VIII	All
Temperature in year to summer of survey	-0.47	-0.07	-0.22	-0.03	0.36	0.02	0.01	-0.38	-0.33
Temp. in year preceding summer of survey	-0.04	-0.01	-0.24	-0.02	-0.25	0.12	-0.07	-0.32	-0.01
100mm soil temp, yr to summer of survey	-0.22	-0.11	-0.59	-0.19	0.22	-0.18	0.01	-0.57	-0.31
100mm soil temp, yr preceding summer of survey	0.04	-0.31	-0.60	0.15	0.23	-0.17	-0.10	-0.48	-0.19
Mean maximum temp yr to summer of survey	-0.53	-0.02	-0.26	-0.09	0.21	-0.10	-0.08	-0.37	-0.30
Mean max. temp yr preceding summer of survey	-0.08	0.00	-0.24	-0.02	-0.32	0.07	-0.09	-0.26	0.01
Mean minimum temp yr to summer of survey	-0.42	-0.13	-0.24	0.05	0.47	0.09	0.09	-0.27	-0.38
Mean min. temp yr preceding summer of survey	-0.06	-0.05	-0.29	0.02	-0.13	0.14	-0.05	-0.38	-0.08
Rainfall yr to summer of survey	-0.14	0.10	0.03	0.07	0.52	0.13	-0.06	0.03	-0.08
Rainfall yr preceding summer of survey	0.00	0.20	0.18	0.02	0.48	0.15	-0.17	-0.09	0.06

(c) S-radius	aggregate class								
	I	II	III	IV	V	VI	VII	VIII	All
Temperature in year to summer of survey	-0.10	0.17	0.12	0.09	-0.12	-0.07	0.49	0.50	-0.33
Temp. in year preceding summer of survey	0.06	0.04	0.11	0.29	0.15	0.01	0.11	0.31	-0.01
100mm soil temp, yr to summer of survey	-0.15	-0.43	-0.22	0.16	0.06	0.11	0.59	0.59	-0.09
100mm soil temp, yr preceding summer of survey	0.30	-0.54	-0.22	-0.06	-0.04	0.12	0.43	0.50	-0.05
Mean maximum temp yr to summer of survey	-0.18	0.19	0.03	0.15	0.00	0.05	0.46	0.47	-0.24
Mean max. temp yr preceding summer of survey	0.03	0.02	0.08	0.28	0.17	0.08	0.03	0.23	0.04
Mean minimum temp yr to summer of survey	-0.05	0.12	0.09	-0.01	-0.20	-0.15	0.51	0.41	-0.39
Mean min. temp yr preceding summer of survey	0.08	0.05	0.06	0.26	0.12	-0.08	0.21	0.44	-0.09
Rainfall yr to summer of survey	0.44	0.10	0.25	-0.12	-0.38	-0.12	0.34	0.02	-0.22
Rainfall yr preceding summer of survey	0.57	0.05	0.29	0.00	-0.39	-0.19	0.32	0.18	-0.12

(d) R- radius	aggregate class								
	I	II	III	IV	V	VI	VII	VIII	All
Temperature in year to summer of survey	0.01	0.08	0.14	0.05	-0.39	0.16	-0.40	-0.21	0.29
Temp. in year preceding summer of survey	-0.07	0.13	0.23	0.15	-0.08	-0.17	-0.03	0.05	0.01
100mm soil temp, yr to summer of survey	-0.01	0.12	0.45	0.04	-0.17	0.16	-0.67	-0.15	0.21
100mm soil temp, yr preceding summer of survey	-0.20	0.34	0.48	-0.14	-0.11	0.23	-0.46	-0.08	0.11
Mean maximum temp yr to summer of survey	0.04	0.09	0.19	0.17	-0.39	0.14	-0.29	-0.12	0.26
Mean max. temp yr preceding summer of survey	-0.01	0.15	0.24	0.19	0.00	-0.22	0.06	0.13	0.00
Mean minimum temp yr to summer of survey	-0.01	0.07	0.16	-0.10	-0.34	0.19	-0.49	-0.29	0.34
Mean min. temp yr preceding summer of survey	-0.08	0.13	0.28	0.06	-0.17	-0.02	-0.16	-0.11	0.06
Rainfall yr to summer of survey	-0.14	-0.22	-0.09	0.02	-0.12	0.16	-0.30	-0.16	0.19
Rainfall yr preceding summer of survey	0.16	-0.27	-0.22	0.08	-0.07	0.25	-0.09	-0.16	0.07

Table 3.6 contd.

(e) Ellenberg L score	aggregate class								
	I	II	III	IV	V	VI	VII	VIII	All
Temperature in year to summer of survey	-0.08	0.10	-0.08	0.15	0.02	0.31	0.06	-0.03	0.35
Temp. in year preceding summer of survey	-0.59	-0.16	-0.06	-0.08	0.48	0.02	0.36	0.18	0.31
100mm soil temp, yr to summer of survey	0.16	0.09	-0.26	0.14	0.16	0.01	0.03	0.13	0.20
100mm soil temp, yr preceding summer of survey	-0.65	0.22	-0.31	-0.09	0.02	0.10	0.26	0.24	0.09
Mean maximum temp yr to summer of survey	0.09	0.04	-0.21	0.22	0.23	0.23	0.22	0.10	0.35
Mean max. temp yr preceding summer of survey	-0.52	-0.17	-0.13	-0.04	0.53	-0.10	0.37	0.42	0.30
Mean minimum temp yr to summer of survey	-0.11	0.21	0.02	0.08	-0.21	0.31	-0.08	-0.13	0.29
Mean min. temp yr preceding summer of survey	-0.62	-0.10	-0.01	-0.13	0.37	0.19	0.33	-0.13	0.31
Rainfall yr to summer of survey	-0.62	-0.14	0.00	0.12	-0.25	-0.07	-0.11	0.41	0.14
Rainfall yr preceding summer of survey	-0.83	-0.09	0.15	0.16	-0.18	0.17	0.16	0.37	0.08

(f) Ellenberg N score	aggregate class								
	I	II	III	IV	V	VI	VII	VIII	All
Temperature in year to summer of survey	0.73	-0.16	-0.35	-0.11	-0.13	0.19	-0.35	-0.13	0.02
Temp. in year preceding summer of survey	0.20	-0.09	-0.14	-0.27	-0.30	-0.30	0.14	-0.17	-0.36
100mm soil temp, yr to summer of survey	0.32	0.34	0.00	-0.03	-0.25	0.09	-0.45	-0.06	-0.06
100mm soil temp, yr preceding summer of survey	0.27	0.45	0.27	0.21	-0.23	-0.09	-0.16	-0.17	-0.18
Mean maximum temp yr to summer of survey	0.66	-0.19	-0.19	-0.15	-0.27	0.14	-0.28	0.01	-0.03
Mean max. temp yr preceding summer of survey	0.10	-0.05	-0.02	-0.26	-0.32	-0.31	0.19	-0.08	-0.36
Mean minimum temp yr to summer of survey	0.77	-0.08	-0.34	-0.02	-0.01	0.25	-0.37	-0.26	0.12
Mean min. temp yr preceding summer of survey	0.34	-0.11	-0.20	-0.22	-0.31	-0.25	0.06	-0.24	-0.31
Rainfall yr to summer of survey	0.31	-0.07	-0.50	0.02	0.29	0.21	-0.36	-0.39	0.09
Rainfall yr preceding summer of survey	-0.02	-0.15	-0.63	0.01	0.34	0.08	-0.24	-0.39	0.04

(g) Ellenberg R score	aggregate class								
	I	II	III	IV	V	VI	VII	VIII	All
Temperature in year to summer of survey	0.02	0.16	-0.53	0.04	-0.05	0.36	0.00	0.00	0.04
Temp. in year preceding summer of survey	0.36	-0.04	-0.08	-0.20	-0.30	-0.09	0.08	-0.25	-0.08
100mm soil temp, yr to summer of survey	-0.04	0.29	-0.55	0.02	-0.09	0.04	-0.10	0.19	-0.12
100mm soil temp, yr preceding summer of survey	0.39	0.36	-0.47	0.04	-0.19	0.00	-0.02	-0.03	-0.25
Mean maximum temp yr to summer of survey	0.03	0.17	-0.37	0.03	-0.20	0.41	0.00	0.12	0.05
Mean max. temp yr preceding summer of survey	0.37	-0.01	0.02	-0.19	-0.31	-0.14	0.06	-0.18	-0.08
Mean minimum temp yr to summer of survey	-0.05	0.18	-0.61	0.08	0.07	0.24	0.02	-0.08	0.04
Mean min. temp yr preceding summer of survey	0.31	-0.01	-0.18	-0.15	-0.31	0.04	0.21	-0.19	-0.06
Rainfall yr to summer of survey	0.39	-0.17	-0.63	0.00	0.43	-0.23	-0.37	-0.31	-0.06
Rainfall yr preceding summer of survey	0.13	-0.29	-0.52	-0.03	0.43	-0.01	-0.32	-0.32	-0.13

(h) Ellenberg W score	aggregate class								
	I	II	III	IV	V	VI	VII	VIII	All
Temperature in year to summer of survey	-0.11	-0.05	-0.25	-0.24	0.22	0.03	0.56	-0.02	-0.25
Temp. in year preceding summer of survey	0.00	0.13	-0.61	-0.32	-0.08	-0.05	0.12	-0.29	-0.09
100mm soil temp, yr to summer of survey	-0.18	0.21	0.20	-0.28	0.21	-0.23	0.49	-0.04	-0.16
100mm soil temp, yr preceding summer of survey	0.23	0.04	-0.21	-0.04	0.28	-0.16	0.30	-0.03	-0.01
Mean maximum temp yr to summer of survey	-0.30	0.03	-0.31	-0.30	0.14	0.02	0.57	0.04	-0.19
Mean max. temp yr preceding summer of survey	-0.10	0.16	-0.63	-0.29	-0.14	-0.10	0.07	-0.18	-0.07
Mean minimum temp yr to summer of survey	0.04	-0.15	-0.19	-0.13	0.30	-0.01	0.47	0.00	-0.32
Mean min. temp yr preceding summer of survey	0.11	0.09	-0.59	-0.33	0.03	-0.01	0.18	-0.26	-0.13
Rainfall yr to summer of survey	0.18	-0.05	0.32	0.23	0.34	0.14	0.33	0.21	0.02
Rainfall yr preceding summer of survey	0.64	0.11	0.30	0.06	0.27	0.33	0.68	0.24	0.24

Table 3.7 Correlations (r) between Ellenberg R score and climate in 3 month periods. Previous summer is the period June - August of the year before the survey. Autumn is September - November, Winter is December - February, Spring is March - May and survey summer is June - August in the period the survey took place. Significant ($p<0.05$) results are indicated by shading. Other variables analysed on this basis are given in Appendix 6

	aggregate class								
	I	II	III	IV	V	VI	VII	VIII	All
Temperature previous Summer	-0.35	-0.14	0.12	0.16	0.21	0.50	-0.34	0.32	0.20
Temperature Autumn	-0.40	-0.12	-0.19	-0.03	0.12	0.34	-0.44	0.11	0.09
Temperature Winter	0.18	0.19	-0.63	0.05	0.02	0.06	0.12	-0.12	-0.03
Temperature Spring	0.34	0.23	-0.08	-0.16	-0.42	-0.29	0.42	-0.22	-0.16
Temperature survey Summer	-0.02	-0.06	0.58	-0.02	-0.08	0.00	-0.12	-0.07	-0.04
100 mm Soil temp. previous Summer	-0.42	-0.31	0.14	0.12	0.37	0.52	-0.45	0.43	0.13
100 mm Soil temp. Autumn	-0.45	0.04	-0.43	0.04	0.08	0.19	-0.42	0.29	-0.10
100 mm Soil temp. Winter	0.37	0.27	-0.65	0.10	-0.01	0.05	-0.13	0.05	-0.06
100 mm Soil temp. Spring	0.46	0.19	-0.25	-0.10	-0.27	-0.12	0.31	-0.12	-0.16
100 mm Soil temp. survey Summer	0.17	-0.34	0.03	0.03	0.05	0.09	-0.05	-0.27	-0.11
Mean maximum temp. previous Summer	-0.28	-0.17	0.27	0.12	0.12	0.45	-0.32	0.33	0.19
Mean maximum temp. Autumn	-0.36	-0.04	-0.14	-0.03	0.09	0.30	-0.50	0.24	0.04
Mean maximum temp. Winter	0.13	0.20	-0.63	0.05	0.03	0.03	0.18	-0.09	-0.02
Mean maximum temp. Spring	0.45	0.20	0.01	-0.13	-0.50	-0.22	0.36	-0.18	-0.13
Mean maximum temp. survey Summer	-0.11	-0.08	0.52	0.01	0.22	-0.05	-0.23	-0.10	0.04
Mean minimum temp. previous Summer	-0.31	0.03	-0.25	0.16	0.27	0.41	-0.26	0.28	0.16
Mean minimum temp. Autumn	-0.53	-0.14	-0.24	-0.03	0.20	0.33	-0.40	0.02	0.15
Mean minimum temp. Winter	0.20	0.15	-0.65	0.10	-0.01	0.17	0.11	-0.13	-0.01
Mean minimum temp. Spring	0.18	0.28	-0.23	-0.11	-0.25	-0.34	0.46	-0.25	-0.20
Mean minimum temp. survey Summer	0.14	0.03	0.41	-0.04	-0.49	0.19	0.25	0.09	-0.08
Rainfall previous Summer	0.26	0.30	-0.55	0.05	-0.11	-0.23	0.00	-0.14	-0.02
Rainfall Autumn	0.41	-0.30	-0.33	0.05	0.31	-0.14	-0.43	-0.42	-0.03
Rainfall Winter	0.15	-0.47	-0.14	0.08	0.56	0.24	-0.36	-0.19	0.00
Rainfall Spring	-0.17	-0.06	-0.44	-0.17	0.29	-0.21	-0.13	0.00	-0.10
Rainfall survey Summer	-0.01	0.20	-0.09	-0.02	-0.56	0.32	0.39	0.09	-0.16

4. Discussion of results

The results clearly show that vegetation did vary significantly from year to year and this variation was substantial in some vegetation types. This is an important finding, as it has not, to our knowledge, been investigated before across such a wide range of sites and vegetation types. This study is also unusual in that we have used simple species presence / absence data at the plot level, which would be expected to be more stable than cover estimates or frequency measures within plots. There were differences between vegetation types and between sites, differences between sites largely relecting which vegetation types present at each.

The classification of a high proportion of the plots changed between years. Vegetation shows a continuous range of variation so it is not unexpected that the presence or absence of one or two species may be all that is required to move some plots from one class to another. However, some classes are more prone to change than others, so for example, AC VI, Upland Wooded can grade into either Lowland Wooded (AC V) or Moorland grass / mosaics (AC VII) under different circumstances. Other classes such as Crop/ Weed (AC I) or heath / bog (AC VIII) have a more distinctive set of species and so are less sensitive to small changes in vegetation composition.

The level of variability of the vegetation indices within vegetation classes tends to parallel the degree of disturbance. Thus the most disturbed sites, the arable ones (AC I crops/ weeds), show the greatest variability for all of the vegetation indices; this is not surprising as cultivation allows a new species assemblage to develop each year. The differences between years, although large, tended not to be significant in AC I, because of large field to field variability. The fertile grasslands (AC III) are also relatively variable. They are not disturbed to the same degree as arable land but regular cutting or close grazing prevents a dense canopy persisting and poaching by livestock and vehicle tracks also create gaps in the sward. The number of species in these grasslands is small, so the presence or absence of a few weed species colonising short-term gaps may have a relatively large impact on the vegetation indices. This is especially true since our analysis (like most of those of the Countryside Surveys) was based on presence / absence rather than any measure of abundance within plots.

The changes in C and R radii suggest that the decrease in species numbers in fertile grasslands(AC III) between approximately 1997 and 1999 reflect a shifting balance between ruderal species and the more competitive grasses, which dominate these grasslands, of which *Lolium perenne* is particularly important. This may be explained if gaps (which can be colonised by ruderals) were more common in the middle of the 1990s and closed over in later years. This may in turn reflect a recovery of soil water contents after the drought of 1995 and subsequent years. (Soil water content only returned to pre-drought levels in the summer of 1997 at Wytham; Morecroft *et al.*, 2000). In other studies (Morecroft *et al*. in press), an increased frequency of annuals was found *within* grassland plots at Drayton and Wytham in 1996 compared to 1994. It is notable that the biggest changes were found in 1999 following a very wet summer in 1998 and where records are available (Table 3.5) there do seem to have been fewer ruderal weeds in 1994 before the drought than 1996-1998, after it.

Infertile Grasslands (Aggregate Class IV) and tall herb / grasslands (Aggregate Class II) are less variable than the Fertile Grasslands, but differences between years were nevertheless detected. In particular a shift towards competitors and higher Ellenberg fertility values does seem to have taken place in Infertile Grasslands in 1999 compared to other years. Unlike the Fertile Grasslands, the shift was away from stress tolerators rather than ruderals. This may be climatically related, but it is notable that this change parallels those found between the 1978 and 1990 Countryside Surveys, which are best explained by increasing eutrophication (Bunce *et al.* 1999); this trend has also been continued between 1990 and 1998 (Haines - Young *et al.*, 2000). Fertiliser applications to these types of grasslands are not likely to be a widespread factor at the ECN sites, but atmospheric nitrogen deposition levels continue to be high across the country.

Woodlands of both 'upland' and 'lowland' types (aggregate classes V and VI) can be quite variable and some significant differences were found. Much of this variability is intrinsic to the system: woodland management causes dramatic changes in the physical environment of ground vegetation, but it is patchy and takes place at long time intervals; even in an unmanaged woodland, periodic tree fall can have similar effects. These processes are not synchronised across the ECN sites so it is surprising that significant year to year differences were found.

The predominantly upland vegetation types, VII and VIII, are relatively stable year-to-year. These sorts of vegetation are subject to little disturbance and maintain a close cover of stress tolerant species. Even where gaps do occur, a relatively small number of species adapted to what are typically damp, acidic conditions, can colonise them.

The most likely cause of year-to-year variations in vegetation across the range of sites in this study is differences in the weather, given that were few other large scale perturbations which affected all sites. However, relatively few correlations with meteorological variables were found and those which were do not explain the most significant year to year changes. It is possible that climate is not the cause of the observed year to year fluctuations in vegetation indices, but it is hard to suggest any convincing alternative explanation. It is likely that the time series we currently have available are simply not long enough to ensure the detection of climatic effects. We only have four years continuous run of data at most (for some plots only two years) which is a very small number of cases with which to identify a relationship, and does not allow different combinations of meteorological conditions to be investigated. Climatic variables are also measured for each site as a whole and so must be related to summaries of the vegetation indices for each site; the power of detection is therefore lower than for tests applied at the plot level. It is also likely that some climatic effects are complex, involving for example, long time lags, non-linear responses or interactions between variables. Here again longer data runs would be needed to allow for detailed analysis. As discussed above, the dry conditions between 1995 and 1997 are likely to have been important, but we have too few data from 1994 to be able generalise across all sites and vegetation types.

5. Implications for Countryside Surveys

These results show that the Countryside Survey results must incorporate an element caused by year to year variations in vegetation, but how large is this element? Because we do not have annually recorded data going back to 1990 we cannot say for sure, but we can illustrate the potential scale of the problem. In this section we do this by comparing changes between 1990 and 1998, with those between 1998 and 1999 (the two years with most comprehensive coverage), expressing the changes as percentages.

5.1 Changes in aggregate vegetation class classification

Overall (all plot types), 30% of plots changed aggregate vegetation class between 1990 and 1998 (unpublished CS2000 data); the equivalent figure for 1978 - 1990 was 38% (From Bunce *et al*., 1999, Annex 15a). Between 1998 and 1999, 12% of plots changed classification. On this basis we might suggest that, about a third of the changes in aggregate classes between 1990 and 1998 could be the result of annual fluctuations, assuming the changes between 1998 and 1999 are typical (see section 2). It is important however to look at the data for each vegetation class separately. Fig. 5.1 is taken from the main CS2000 report (Haines-Young *et al*., 2000) summarises net changes between aggregate classes for 1990 to 1998. Table 5.1 gives a complete matrix of change. Brief comments on potential impact of interannual variability for each of the aggregate vegetation classes are given in Table 5.2

Figure 5.1

Net movement of CS plots between aggregate vegetation classes from 1990 to 1998; GB all plots

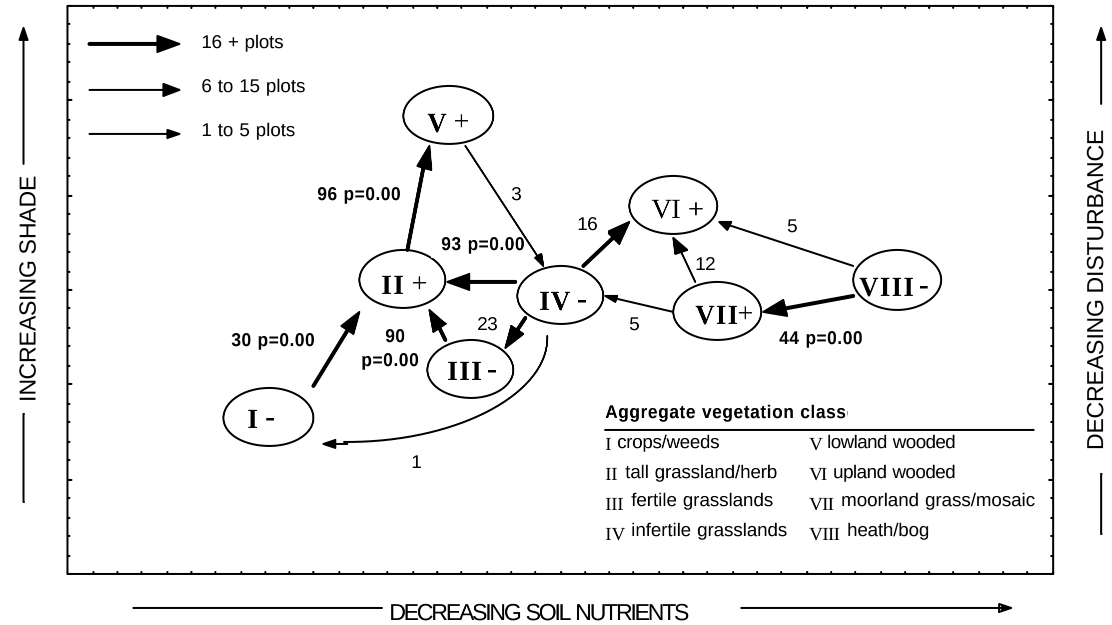


Table 5.1 Changes in CS2000 plot classification between aggregate vegetation classes. Data are from all plot types and all of Great Britain. Significant ($p<0.05$) differences are shown shaded

					98/9					
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	1	**287**	60	94	7	5				453
	2	30	**1453**	206	90	264	24	1	1	2069
	3	73	296	**860**	227	6	5	2		1469
90	**4**	8	183	250	**1356**	12	77	76		1962
	5	4	168	4	15	**694**	31			916
	6		36	6	61	47	**375**	65	10	600
	7		1	7	81		77	**879**	80	1125
	8		1		1		15	124	**727**	868
		402	2198	1427	1838	1028	604	1147	818	

Class I Crops / weeds. Interchange with classes II and III can occur on a yearly basis in the normal course of agricultural practice.

Class II Tall grass / herbs. We have too few data from the ECN work to make firm statements; further work is required. This should be a priority as AC II was one of the more changeable classes in CS2000 results.

Class III Fertile grasslands. Transfers between AC III and AC II were found in both 1990 - 1998 and inter-annual results (Fig. 5.1; Table 3.1) and an impact of year to year fluctuations in factors such as climate is likely. However, there was no evidence of a consistent change in plot classification from AC III to AC II, as was found between 1990 and 1998, in or around 1998: the detected trend is likely to be longer term. Changes to lowland wooded vegetation (AC V) between 1990 and 1998 are not likely to be short-term fluctuations.

Class IV Infertile grassland. Between 1990 and 1998, this class showed losses to and gains from several other classes, with a relatively large number of plots changing from ACIV to ACII. Module 10 revealed interchanges with classes II, III, VI and VII; with some plots changing in and out of ACIV (Appendix 5) and it is possible that year-to-year variability is having some influence on the results for this vegetation class, though it is not likely to be the main explanation of 1990 - 1998 changes.

Class V Lowland wooded. Between 1990 and 1998 there were large net gains to this group from ACII (mostly in hedgerows) and small net losses to ACIV. In Module 10 this class was found to be relatively stable with respect to these groups and there is no reason to suspect a major influence of climate on the 1990 - 1998 results.

Class VI Upland Wooded. This vegetation class was found to change in Module 10 results with particularly frequent transfers to AC V and AC VII. An influence of year to year changes reflecting forestry work and bracken management as well as climate maybe influencing the main survey results, though relatively few major shifts were detected in CS2000. This group did show large changes between 1978 and 1990 and there is no reason to suppose this was not genuine.

Class VII Moorland grass / mosaic. The main survey found relative stability in this group, though there were transfers to AC VI and AC IV. Year to year variability between these classes and AC VII was found and may be responsible for producing or concealing some trends in the larger survey.

Class VIII, Heath / bog. This was a stable classification in Module 10 results, but it was possible for plots to move between AC VII and AC VIII in both directions giving some cause for concern about at least the magnitude of the detected shift from AC VIII to AC VII in CS2000.

5.2 Changes in vegetation indices

Figs. 5.2 - 5.4 put side by side the percentage changes in vegetation indices between 1990 and 1998 and the 1998 - 1999 vegetation index changes reported here. Changes in these indices appear to be less robust to annual fluctuations than changes in plot classification. For all indices, the percentage changes between 1998 and 1999 are of similar magnitude to those between 1990 and 1998 and in many cases are actually larger. This greater sensitivity, compared to changes in classification, is not unexpected as these comparisons are based on plots that have not changed classification so tend to reflect smaller changes in vegetation. It should also be noted that because of the smaller sample size we would expect greater variation in means for annual data than the main survey. However, if this were a major factor and there were fewer real differences between 1998 and 1999 than between 1990 and 1998, we would expect fewer significant differences to be detected in the 1998-99 comparison than for 1990-98. In fact there were 15 significant differences for the 1990-98 comparisons and 14 for the 1998-99 comparisons (in both cases out of a total of 64 tests), suggesting this is not the case.

In many cases the direction of the change between 1998 and 1999 was the same as between 1990 and 1998 and may represent an ongoing trend. The increase in mean Ellenberg numbers in infertile grassland and moorland / grass mosaic is a good example where this may well be the case. This is not universally true however and the similarity in magnitude of the differences over one year and eight years is a cause for some concern. It would certainly be wise to exercise caution in interpreting changes in AC I and ACIII. ACII is also likely to show annual variability but, as with plot classification, we have too few data to comment properly on this.

Fig. 5.2 Comparison of changes in number of species per plot between 1990 and 1998 in CS2000 data and between 1998 and 1999 in ECN annual data. Data are expressed as percentages of the starting value. Error bars for ECN annual data are standard errors. Significant differences (p<0.05) are indicated by an asterisk (*).

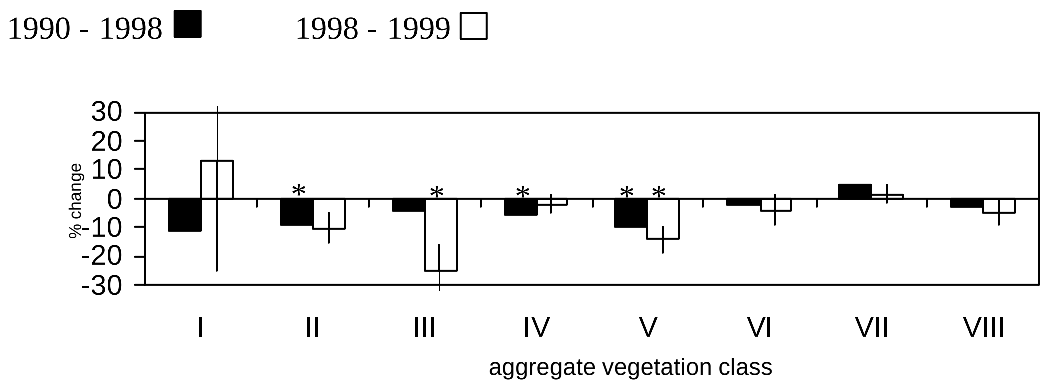
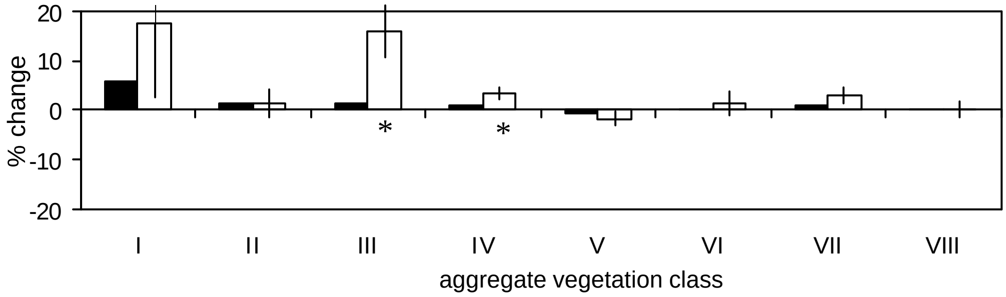


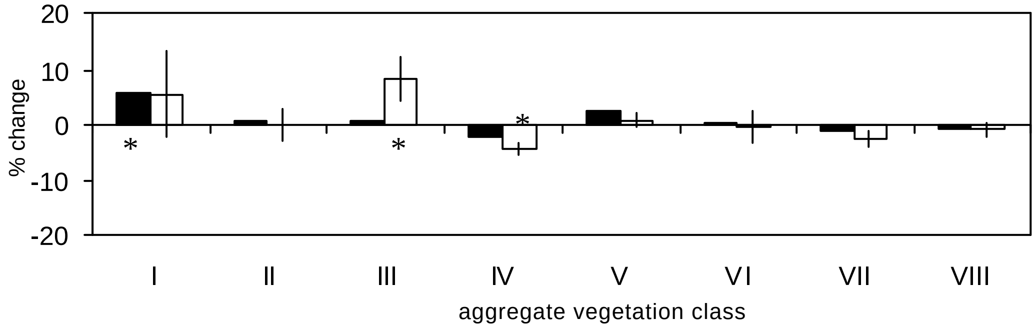
Fig. 5.3 Comparison of changes in CSR radii between 1990 and 1998 in CS2000 data and between 1998 and 1999 in ECN annual data. Data are expressed as percentages of the starting value. Error bars for ECN annual data represent standard errors. Significant differences (p<0.05) are indicated by an asterisk (*).

1990 - 1998 ■ 1998 - 1999 □

(a) C radius



(b) S radius



(c) R radius

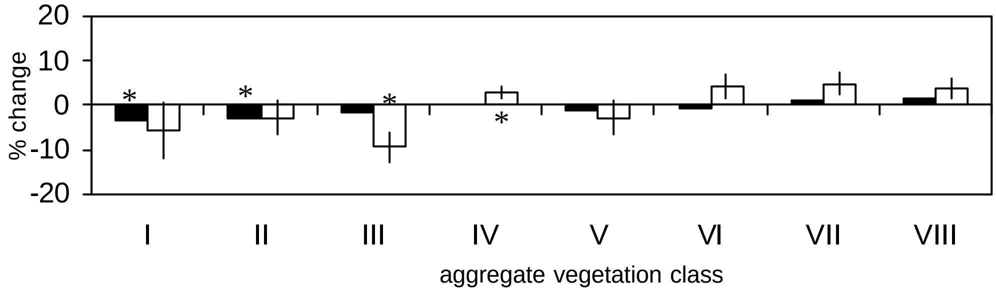
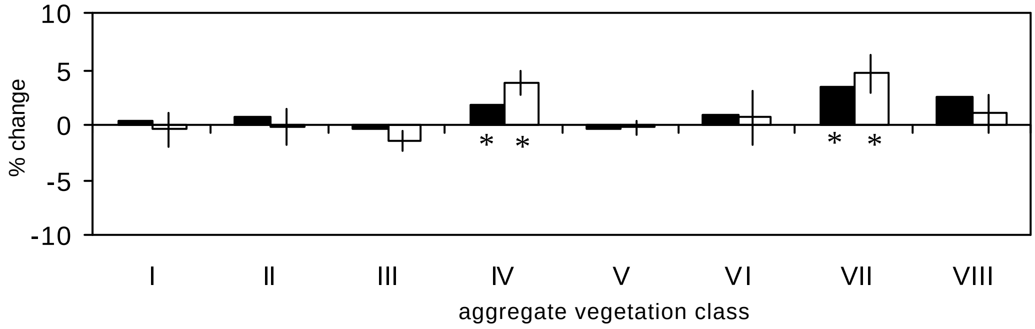


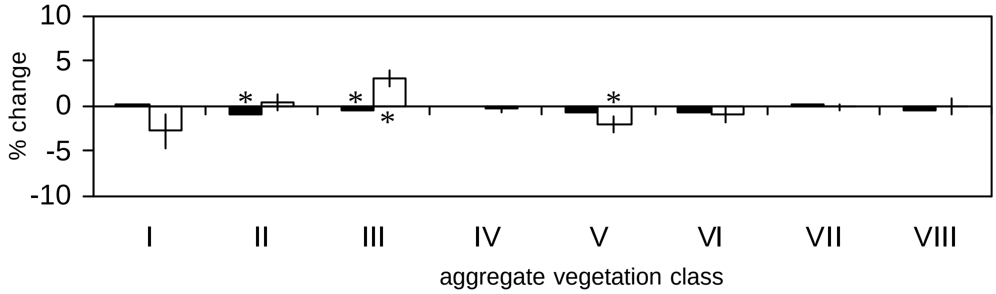
Fig. 5.4 Comparison of changes in Ellenberg indices between 1990 and 1998 in CS2000 data and between 1998 and 1999 in ECN annual data. Data are expressed as percentages of the starting value. Error bars for ECN annual data are standard errors. Significant differences ($p<0.05$) are indicated by an asterisk (*).

1990 - 1998 ■ 1998 - 1999 □

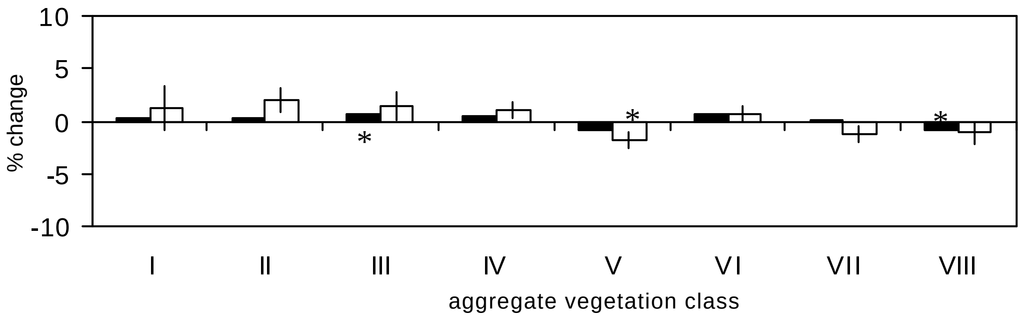
(a) Ellenberg N



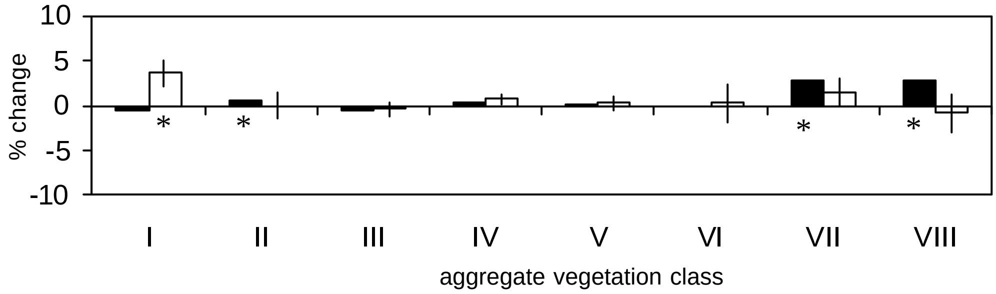
(b) Ellenberg L



(c) Ellenberg W



(d) Ellenberg R



Would CS2000 results have been different if the main survey had been carried out in the years immediately before or after 1998? Because the direction of change was similar between 1998 - 1999 as between 1990 - 1998, the basic finding are unlikely to have been affected by carrying out the all of the survey in 1999. However, the magnitude of some changes are likely to have been quite different if the main survey was carried out in 1999 and this could have altered the statistical significance of some results. The relative instability of fertile grasslands has already been noted and it is interesting that a major decline in their biodiversity may have been detected by a 1999 main survey, which could not truly be regarded as a long-term change. In general, our results suggest that most changes would have been detected more strongly in 1999 than 1998 and this needs to be borne in mind in further analysis of the main survey data when comparing data collected in both 1998 and 1999. A 1997 survey would probably also have produced a largely similar pattern of results to 1998, but again it would be unwise to assume that similar magnitudes of change would be found.

6. Recommendations

We have detected year to year changes in vegetation and shown that they are large enough to influence the results of the Countryside Surveys. However, we have not been able to establish correlations with climate or accurately quantify the impact, almost certainly because we do not have a long enough time series. It is therefore essential that annual monitoring of vegetation continues, if it is to be possible to make allowances for weather conditions in interpreting the results of future large-scale, but intermittent, monitoring exercises. This is all the more important in the context of climate change as periods of extreme weather such as droughts will probably become more frequent (Hulme & Jenkins, 1998). Yearly vegetation monitoring would also add to our understanding of the mechanisms underlying vegetation changes.

Is ECN monitoring a suitable basis for such a study? The fact that we could detect significant differences between years and discriminate between different vegetation types shows that the method used was fit for its intended purpose. Further information on the impact of different plot designs would however be useful when comparing between methodologies. The very detailed information available for each ECN site makes these sites particularly well suited for an ongoing study of annual vegetation changes. We have made extensive use of climate data, but information on soil type, hydrology and animal populations could all be invaluable for interpreting vegetation data. Large-scale changes in management are unusual at most ECN sites and where management practices do change, records are normally kept. This means that in some respects ECN plots can act as 'controls' against which to judge land use change in the wider countryside. Personal contact is often important in understanding site - specific changes and locally based ECN site managers can normally answer detailed questions about site history and management. Future analysis should take advantage of this wealth of background knowledge to gain a fuller understanding of the processes taking place at the plot scale. This study also benefited from using locally based staff to locate and mark permanent plots in advance of the surveyors' visits. Further advantages of using ECN sites for a study of this sort include the wide geographical range of locations and the existing time series for vegetation data, which this project has contributed to. Annual vegetation monitoring would also add value to ECN monitoring itself.

The low number of plots in aggregate vegetation class II is a cause of concern as it makes it unlikely that significant differences or relationships to climate will be detected. Any future recording programme should aim to establish new plots, perhaps along linear features, to address this deficit. It would also be useful to bring in the more recently designated ECN sites in Snowdonia and the Cairngorms, which would improve coverage at the upper end of the range of altitudes. A further study to compare results between ECN and Countryside survey types of plots is desirable. This could be done relatively easily by superimposing a Countryside Survey design plot onto each ECN plot and recording both for a few years.

We would therefore recommend that the current monitoring programme be continued and extended in the following ways:

1. Continue monitoring of plots that were recorded in 1998 and 1999 up to at least the next main Countryside Survey and preferably indefinitely.
2. Develop analysis further to better understand processes and eventually enable the effects of climate on inter-annual variability in vegetation to be modelled.
3. Set up additional - probably linear - plots in vegetation of aggregate class II
4. Include plots from the ECN sites at Snowdonia and Cairngorm.
5. Record vegetation in a sample of plots using Countryside Survey and ECN methods.

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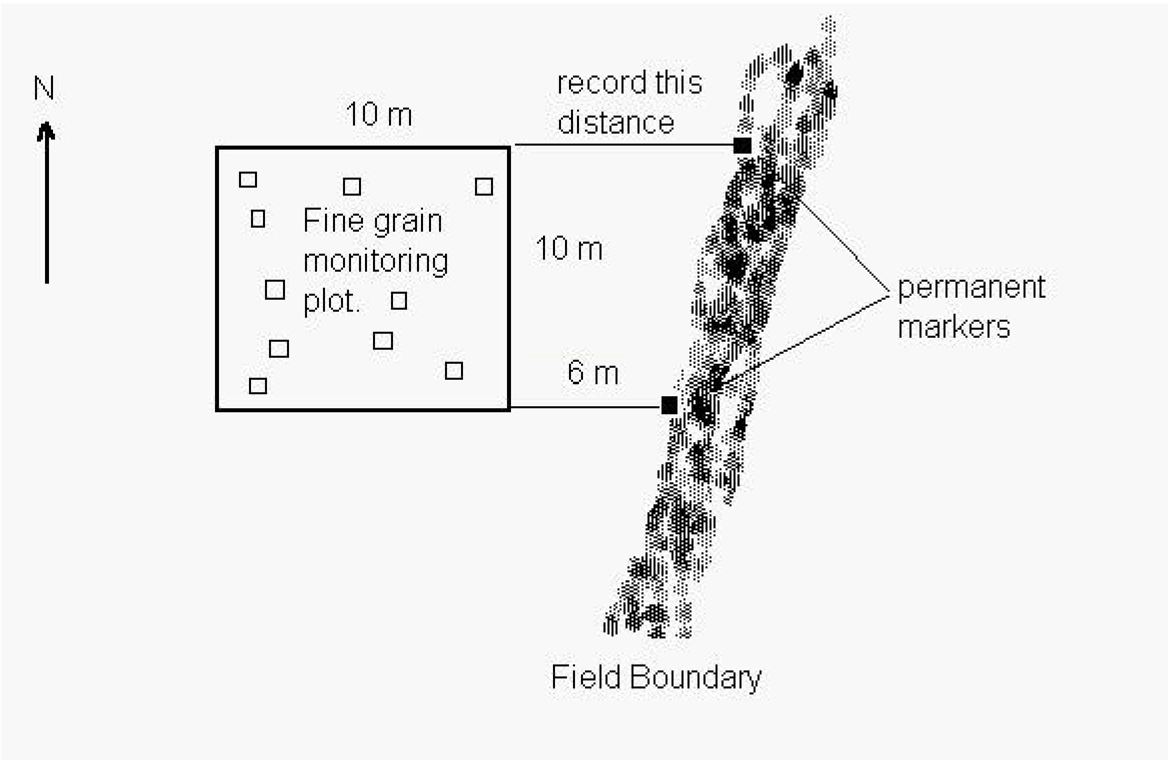
Appendix 1 Protocol for setting up arable vegetation plots - instructions sent to ECN site managers

ECN Annual Vegetation Recording Project 1998
Protocol for establishment of fine grain monitoring plots on arable land.

We have been asked to include arable plots in this assessment in order to help interpret results from the Countryside Survey. This protocol has been drawn up to ensure compatibility with this methodology as well as ECN, hence for example, plots are established at the edge of fields.

Five plots should be established on arable land at each suitable ECN site. Plots should include a range of crops typical of the site, but not grass leys, extreme experimental treatments, or unorthodox crops; plots should normally be in different fields. Once a field has been chosen a random point along its boundary should be selected. The plot should be located such that the nearest corner is 6 m from this point on the boundary, where a permanent marker should be placed (Fig. 1). The nearest corner should be due North, South, East or West of the boundary point. A second marker should be placed in the boundary due North, South, East or West of the second closest corner and the distance between the marker and plot corner recorded. Which corner (NE, SE, SW, NW) is closest to each permanent marker should also be noted, together with the location of the marker with respect to an easily identified landmark (e.g. gate, building, tree). Plot information (grid reference etc.) for arable plots should be recorded in the same way as for other ECN plots.

Figure 1. Diagram to illustrate position of plot relative to field boundary



Because herbicide usage will affect which arable weeds are present, records of herbicide treatment should be kept (see Table 1). It would be helpful to have records from the present growing season onwards.

Table 1 EXAMPLE PROFORMA FOR USE IN ARABLE CROPS

<table>
<tr><th colspan="4">HERBICIDE USAGE RECORD</th></tr>
<tr><td colspan="2">ECN SITE</td><td colspan="2">FIELD NAME/No.</td></tr>
<tr><td>RECORDER</td><td>CROP</td><td>VARIETY</td><td>DATE SOWN</td></tr>
<tr><th>DATE</th><th>PRODUCT</th><th>Active ingredient</th><th>Rate per ha</th></tr>
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This work will be repeated next year using the same permanent plots. It is possible that the monitoring may be continued in subsequent years. Inevitably crops will vary from year to year and this will confound interpretation of results; in the long term this should become less important as crops return to the original fields. In the short term extra plots may be established next year in order to track trends in common crops such as wheat.

Appendix 2 Summary of vegetation monitoring plots in the Countryside Survey.

Name	**Area and shape**	**Location**	**Years for which comparisons can be made**
Main	200 m^2 square	random but not on linear features	1978, 1990, 1998
Habitat	4 m^2 square	random from semi-natural habitats not included in main plots	1990, 1998
Boundary	10 x 1m linear	nearest field boundary to main plot	1990, 1998
Hedge	10 x 1m linear	random	1978, 1990, 1998
Streamside	10 x 1m linear	random + selected	1978, 1990, 1998
Roadside	10 x 1m linear	random + selected	1978, 1990, 1998

Appendix 3 Surveyors used to collect data used in analyses present here. P. Wilson (Wessex Environmental Associates) on some occasions worked with M. Read, who was responsible for some of the identifications (specific surveyors are recorded for each plot).

Site	**1994**	**1996**	**1997**	**1998**	**1999**
Alice Holt	-	M.Bracken	P. Wilson	P. Wilson	P. Wilson
Drayton	S. Corbett	S. Corbett	P. Wilson	P. Wilson	P. Wilson
Glensaugh	-	D. Henderson	G. Common	D. MacCutcheon	D. MacCutcheon
Hillsborough	-	R.Anderson/ N.McDowell/ F.Mulholland	P. Wilson	P. Wilson	P. Wilson
Moorhouse-Upper Teesdale	-	D. MacCutcheon	G. Common	D. MacCutcheon	D. MacCutcheon
North Wyke	E. Sothern	E. Sothern	P. Wilson	P. Wilson	P. Wilson
Porton	-	P. Wilson	P. Wilson	P. Wilson	D. MacCutcheon
Rothamsted	-	C. Hallam	P. Wilson	P. Wilson	P. Wilson
Sourhope	-	G. Common	G. Common	D. MacCutcheon	D. MacCutcheon
Wytham	M. Morecroft/ C. Walls	M. Morecroft	P. Wilson	P. Wilson	P. Wilson

Appendix 4 Number of plots at each site used in analyses and length of period of observation

	Number of years of observation				
Site	2	3	4	5	Total
Alice Holt		6	9		15
Drayton	1		2	10	13
Glensaugh		4	10		14
Hillsborough		2	10		12
Moor House/Upper Teesdale		11	14		25
North Wyke	8		6	5	19
Porton	6		10		16
Rothamsted	5		10		15
Sourhope		1	10		11
Wytham	5	2	1	10	18
Total	25	26	82	25	158

Appendix 5 Plots which changed aggregate vegetation class.

Site	Plot no.	aggregate class in each year surveyed				
		1994	1996	1997	1998	1999
Alice Holt	414		6	6	5	6
	418		6		8	8
	419		5	2	6	5
	449		5		6	5
Drayton	393	3	3		1	3
	629	3	1	3	3	2
	745	3	3	2	2	2
	746	3	2	2	2	2
Hillsborough	31		6	5	5	5
	237		5		6	6
	243		2	6	6	6
	277		6	4	2	6
	281		3	2	2	2
Moor House/Upper Teesdale	19		7		8	7
	71		7	6	6	7
	226		6	6	7	7
	390		7		6	7
	411		4		7	4
	501		7		7	4
	502		8		7	7
North Wyke	118	4	4	4	4	3
	256	3	2		3	3
	329		6	5	5	5
	343	4	4	6	7	7
	344	6	4	7	4	6
Porton	999		2	4	2	4
	1002				1	2
	1004				1	0*
Sourhope	30		7	8	7	7
	59		6	7	7	7
	277		7	4	4	4
	436		6	7	7	7
Wytham	32	6	6	6	5	5
	72	2	5	5	5	5
	370	4	4	2		2
	423				1	2

*0 represents a plot which could not be classified under the CVS.

Appendix 6 Correlations between quarterly climate data and vegetation indices. Explanation in Table 3.11

(a) number of species	aggregate class								
	1	2	3	4	5	6	7	8	All
Temperature previous Summer	-0.27	-0.03	0.30	0.23	-0.25	0.34	0.03	0.14	0.15
Temperature Autumn	-0.34	0.21	0.04	0.18	-0.18	0.32	-0.19	-0.23	-0.11
Temperature Winter	-0.42	0.16	-0.26	0.24	0.31	0.21	0.18	-0.04	-0.33
Temperature Spring	-0.40	0.22	-0.15	0.14	0.37	-0.03	0.33	0.20	0.10
Temperature survey Summer	0.58	-0.13	0.01	-0.10	0.02	-0.24	0.14	0.29	0.19
100 mm Soil temp. previous Summer	-0.24	-0.19	0.70	0.57	-0.20	0.31	-0.32	0.04	0.20
100 mm Soil temp. Autumn	-0.56	-0.24	-0.12	0.10	-0.04	0.15	-0.02	-0.12	-0.18
100 mm Soil temp. Winter	-0.51	-0.12	-0.32	0.25	-0.09	0.21	-0.05	-0.11	-0.43
100 mm Soil temp. Spring	-0.26	0.36	-0.16	0.16	0.57	0.14	0.40	0.25	0.16
100 mm Soil temp. survey Summer	0.77	-0.15	0.02	-0.15	0.07	-0.22	0.50	0.24	0.15
Mean maximum temp. previous Summer	-0.20	-0.04	0.31	0.19	-0.28	0.29	-0.03	0.17	0.26
Mean maximum temp. Autumn	-0.37	0.25	0.11	0.24	-0.09	0.30	-0.13	-0.08	-0.05
Mean maximum temp. Winter	-0.45	0.16	-0.23	0.24	0.32	0.18	0.23	-0.03	-0.33
Mean maximum temp. Spring	-0.41	0.25	-0.12	0.16	0.29	-0.02	0.31	0.28	0.25
Mean maximum temp. survey Summer	0.78	-0.22	0.11	-0.19	-0.13	-0.39	0.03	0.20	0.12
Mean minimum temp. previous Summer	-0.50	0.05	0.15	0.23	-0.15	0.32	0.23	0.11	-0.13
Mean minimum temp. Autumn	-0.11	0.19	-0.01	0.11	-0.22	0.30	-0.25	-0.35	-0.20
Mean minimum temp. Winter	-0.42	0.18	-0.30	0.23	0.27	0.33	0.14	-0.07	-0.31
Mean minimum temp. Spring	-0.32	0.11	-0.28	0.07	0.37	-0.02	0.28	0.00	-0.19
Mean minimum temp. survey Summer	-0.18	0.13	-0.16	0.09	0.19	0.28	0.31	0.43	0.34
Rainfall previous Summer	-0.57	0.16	-0.30	-0.05	0.27	-0.05	0.01	-0.19	-0.22
Rainfall Autumn	0.65	-0.04	-0.04	-0.33	0.03	-0.41	-0.07	-0.10	-0.14
Rainfall Winter	0.68	-0.36	0.26	0.05	0.40	-0.10	0.10	0.10	0.06
Rainfall Spring	-0.54	0.15	0.06	0.03	0.53	0.02	-0.11	-0.33	-0.19
Rainfall survey Summer	-0.21	0.18	-0.38	0.44	0.23	0.58	0.51	0.38	0.13

(b) C- radius	aggregate class								
	1	2	3	4	5	6	7	8	All
Temperature previous Summer	-0.21	0.38	0.09	-0.17	0.08	-0.49	-0.23	-0.09	-0.17
Temperature Autumn	-0.21	0.32	-0.07	-0.25	0.09	-0.34	-0.10	-0.07	-0.22
Temperature Winter	-0.29	-0.30	-0.22	0.16	0.45	0.16	0.10	-0.35	-0.27
Temperature Spring	-0.13	-0.27	-0.38	0.05	-0.10	0.38	0.05	-0.11	0.00
Temperature survey Summer	0.38	0.02	0.44	0.02	-0.33	-0.01	0.13	0.15	0.44
100 mm Soil temp. previous Summer	-0.29	0.49	0.35	-0.34	0.08	-0.49	-0.04	-0.39	0.03
100 mm Soil temp. Autumn	0.04	-0.08	-0.29	-0.03	0.33	-0.37	-0.14	-0.45	-0.26
100 mm Soil temp. Winter	-0.35	-0.22	-0.35	0.08	0.33	0.06	-0.14	-0.57	-0.39
100 mm Soil temp. Spring	-0.22	-0.24	-0.47	0.10	0.23	0.32	0.05	-0.15	0.06
100 mm Soil temp. survey Summer	0.44	0.23	0.29	0.15	-0.28	-0.08	-0.07	0.12	0.45
Mean maximum temp. previous Summer	-0.14	0.39	0.11	-0.18	-0.10	-0.47	-0.22	-0.05	-0.08
Mean maximum temp. Autumn	-0.43	0.27	-0.12	-0.29	0.18	-0.31	-0.13	-0.01	-0.26
Mean maximum temp. Winter	-0.33	-0.29	-0.20	0.15	0.49	0.16	0.10	-0.33	-0.26
Mean maximum temp. Spring	-0.04	-0.24	-0.35	0.04	-0.29	0.32	-0.01	-0.13	0.06
Mean maximum temp. survey Summer	0.37	0.07	0.57	0.03	-0.20	-0.06	0.18	0.16	0.41
Mean minimum temp. previous Summer	-0.38	0.23	-0.13	-0.13	0.40	-0.40	-0.21	0.06	-0.40
Mean minimum temp. Autumn	0.12	0.27	-0.02	-0.21	0.12	-0.30	-0.02	-0.13	-0.21
Mean minimum temp. Winter	-0.26	-0.30	-0.29	0.18	0.43	0.07	0.09	-0.34	-0.31
Mean minimum temp. Spring	-0.18	-0.28	-0.43	0.09	0.17	0.36	0.11	-0.06	-0.15
Mean minimum temp. survey Summer	0.05	-0.08	0.01	0.00	-0.37	0.09	-0.05	0.00	0.39
Rainfall previous Summer	-0.36	-0.34	-0.38	0.11	0.36	0.18	-0.12	-0.12	-0.28
Rainfall Autumn	0.53	0.22	0.22	0.08	0.06	0.11	0.11	0.25	0.09
Rainfall Winter	0.33	0.50	0.24	0.05	0.26	-0.30	0.00	-0.29	0.08
Rainfall Spring	-0.61	-0.04	-0.11	-0.08	0.60	0.30	-0.23	-0.29	-0.21
Rainfall survey Summer	-0.16	-0.23	-0.31	-0.05	-0.25	0.04	-0.36	-0.30	0.05

(c) S-radius	aggregate class								
	1	2	3	4	5	6	7	8	All

	1	2	3	4	5	6	7	8	All
Temperature previous Summer	-0.49	0.47	0.03	-0.08	-0.20	0.44	0.11	0.24	0.00
Temperature Autumn	-0.43	0.32	0.01	-0.14	-0.16	0.33	0.23	0.16	-0.10
Temperature Winter	0.19	-0.03	0.17	0.02	-0.15	-0.17	0.48	0.39	-0.35
Temperature Spring	0.28	-0.26	-0.16	0.32	0.24	-0.35	-0.02	0.06	-0.09
Temperature survey Summer	0.36	-0.27	0.04	0.08	0.12	0.02	-0.38	-0.24	0.21
100 mm Soil temp. previous Summer	-0.41	0.45	0.22	-0.10	-0.06	0.48	0.20	0.44	0.15
100 mm Soil temp. Autumn	-0.75	0.28	0.07	-0.27	-0.10	0.37	0.51	0.42	-0.04
100 mm Soil temp. Winter	0.16	-0.11	0.09	0.08	0.02	-0.08	0.59	0.59	-0.19
100 mm Soil temp. Spring	0.46	-0.34	-0.19	0.33	-0.09	-0.36	0.17	0.15	-0.06
100 mm Soil temp. survey Summer	0.43	-0.30	0.16	-0.10	-0.02	0.09	0.10	-0.09	0.29
Mean maximum temp. previous Summer	-0.49	0.41	-0.02	-0.06	-0.08	0.43	-0.03	0.16	0.09
Mean maximum temp. Autumn	-0.33	0.35	-0.02	-0.07	-0.18	0.31	0.30	0.15	-0.14
Mean maximum temp. Winter	0.19	-0.03	0.17	0.01	-0.16	-0.18	0.50	0.37	-0.37
Mean maximum temp. Spring	0.23	-0.28	-0.20	0.31	0.36	-0.31	-0.06	0.07	0.04
Mean maximum temp. survey Summer	0.28	-0.19	0.20	0.00	-0.11	0.12	-0.41	-0.27	0.18
Mean minimum temp. previous Summer	-0.44	0.42	0.02	-0.11	-0.32	0.34	0.53	0.19	-0.25
Mean minimum temp. Autumn	-0.49	0.25	0.05	-0.19	-0.21	0.30	0.21	0.17	-0.12
Mean minimum temp. Winter	0.14	0.02	0.11	-0.01	-0.14	-0.12	0.44	0.41	-0.32
Mean minimum temp. Spring	0.32	-0.22	-0.14	0.26	0.06	-0.33	0.09	0.06	-0.27
Mean minimum temp. survey Summer	0.35	-0.23	-0.26	0.22	0.38	-0.22	-0.35	-0.05	0.24
Rainfall previous Summer	0.05	-0.10	-0.06	-0.04	-0.02	-0.21	0.54	0.16	-0.23
Rainfall Autumn	0.36	-0.09	0.13	-0.08	-0.18	-0.14	-0.06	-0.21	-0.07
Rainfall Winter	0.51	0.18	0.26	-0.23	-0.38	0.33	-0.02	0.33	-0.07
Rainfall Spring	0.08	0.32	0.24	0.01	-0.39	-0.27	0.54	0.34	-0.26
Rainfall survey Summer	0.42	-0.38	-0.20	0.35	0.32	-0.12	0.17	0.40	0.21

(d) R- radius	**aggregate class**								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**All**
Temperature previous Summer	0.10	-0.40	-0.10	-0.08	0.30	0.05	-0.36	-0.21	0.12
Temperature Autumn	0.17	-0.21	0.02	0.07	0.13	0.09	-0.65	-0.26	0.18
Temperature Winter	-0.09	0.20	0.15	-0.10	-0.41	0.08	-0.33	-0.13	0.26
Temperature Spring	-0.06	0.35	0.37	0.22	-0.40	-0.01	0.44	0.16	0.03
Temperature survey Summer	0.12	0.01	-0.36	0.09	0.03	-0.08	0.38	0.28	-0.33
100 mm Soil temp. previous Summer	0.23	-0.54	-0.36	0.11	0.17	-0.07	-0.48	-0.20	-0.04
100 mm Soil temp. Autumn	-0.22	-0.04	0.17	-0.22	-0.10	-0.02	-0.86	-0.14	0.14
100 mm Soil temp. Winter	-0.10	0.17	0.30	-0.15	-0.23	0.08	-0.46	-0.21	0.24
100 mm Soil temp. Spring	-0.02	0.31	0.41	0.18	-0.26	0.13	0.16	0.08	0.00
100 mm Soil temp. survey Summer	0.01	-0.12	-0.28	0.11	0.11	0.05	0.16	0.08	-0.39
Mean maximum temp. previous Summer	0.07	-0.37	-0.10	-0.04	0.32	0.03	-0.22	-0.12	0.02
Mean maximum temp. Autumn	0.28	-0.18	0.08	0.12	0.11	0.00	-0.72	-0.29	0.22
Mean maximum temp. Winter	-0.04	0.18	0.12	-0.07	-0.42	0.07	-0.31	-0.12	0.28
Mean maximum temp. Spring	-0.13	0.38	0.35	0.28	-0.37	0.04	0.52	0.22	-0.05
Mean maximum temp. survey Summer	0.19	-0.09	-0.48	0.04	0.29	-0.18	0.31	0.25	-0.28
Mean minimum temp. previous Summer	0.08	-0.29	0.06	-0.15	0.11	0.08	-0.68	-0.32	0.34
Mean minimum temp. Autumn	0.02	-0.18	-0.03	0.02	0.14	0.09	-0.66	-0.23	0.18
Mean minimum temp. Winter	-0.16	0.20	0.23	-0.17	-0.39	0.18	-0.32	-0.16	0.28
Mean minimum temp. Spring	0.04	0.26	0.40	0.05	-0.37	-0.02	0.20	0.02	0.18
Mean minimum temp. survey Summer	0.02	0.16	0.03	0.18	-0.29	0.23	0.59	0.27	-0.34
Rainfall previous Summer	-0.19	0.26	0.31	-0.05	-0.44	0.14	-0.37	-0.15	0.22
Rainfall Autumn	-0.25	-0.18	-0.19	0.11	0.04	0.22	0.07	-0.07	0.05
Rainfall Winter	0.02	-0.60	-0.27	-0.05	0.28	0.10	-0.04	-0.08	0.11
Rainfall Spring	0.28	-0.14	0.04	0.00	-0.08	-0.05	-0.58	-0.29	0.22
Rainfall survey Summer	0.31	0.36	0.29	0.05	-0.24	0.14	0.32	0.00	-0.16

(e) Ellenberg L scores	aggregate class								
	1	2	3	4	5	6	7	8	All
Temperature previous Summer	0.78	0.07	-0.33	0.21	-0.03	-0.25	0.04	-0.31	-0.02
Temperature Autumn	0.58	0.31	-0.09	0.10	-0.13	-0.08	-0.27	-0.52	0.05
Temperature Winter	-0.39	-0.02	0.06	0.00	-0.14	0.20	0.03	0.12	0.33
Temperature Spring	-0.70	-0.06	0.08	-0.05	0.32	0.33	0.38	0.45	0.26
Temperature survey Summer	-0.57	-0.06	0.13	-0.14	0.10	0.11	0.04	0.02	-0.28
100 mm Soil temp. previous Summer	0.74	-0.28	-0.47	0.39	0.23	-0.40	-0.23	-0.16	-0.02
100 mm Soil temp. Autumn	0.81	0.07	-0.32	-0.07	-0.03	-0.28	-0.14	-0.19	-0.02
100 mm Soil temp. Winter	-0.31	0.00	0.34	-0.04	-0.14	0.21	0.01	0.03	0.30
100 mm Soil temp. Spring	-0.77	-0.02	-0.14	0.01	0.25	0.41	0.36	0.49	0.16
100 mm Soil temp. survey Summer	-0.53	0.05	0.00	0.03	-0.05	0.07	0.36	0.09	-0.24
Mean maximum temp. previous Summer	0.78	-0.01	-0.31	0.14	0.06	-0.24	0.04	-0.34	-0.08
Mean maximum temp. Autumn	0.61	0.31	-0.20	0.21	-0.04	-0.09	-0.20	-0.34	0.08
Mean maximum temp. Winter	-0.37	-0.01	0.02	0.04	-0.14	0.18	0.06	0.18	0.34
Mean maximum temp. Spring	-0.69	-0.10	0.09	-0.03	0.43	0.31	0.41	0.48	0.20
Mean maximum temp. survey Summer	-0.26	0.04	0.12	-0.13	-0.12	-0.09	-0.11	0.06	-0.30
Mean minimum temp. previous Summer	0.68	0.24	-0.30	0.32	-0.19	-0.25	0.00	-0.18	0.11
Mean minimum temp. Autumn	0.60	0.38	-0.05	0.00	-0.27	-0.09	-0.35	-0.58	0.01
Mean minimum temp. Winter	-0.31	0.00	0.06	-0.04	-0.17	0.21	0.03	0.02	0.30
Mean minimum temp. Spring	-0.69	0.03	0.15	-0.08	0.07	0.33	0.29	0.31	0.34
Mean minimum temp. survey Summer	-0.84	-0.14	0.05	-0.14	0.36	0.51	0.41	-0.07	-0.21
Rainfall previous Summer	-0.15	0.01	-0.01	0.04	-0.12	0.04	0.02	0.17	0.23
Rainfall Autumn	-0.49	-0.02	0.46	0.08	-0.23	0.09	-0.17	0.41	-0.05
Rainfall Winter	-0.60	-0.29	-0.28	0.16	-0.13	-0.37	0.12	0.53	0.09
Rainfall Spring	-0.08	-0.08	-0.24	0.05	-0.10	0.01	-0.06	0.04	0.23
Rainfall survey Summer	-0.85	0.15	0.23	-0.01	0.35	0.49	0.73	-0.25	0.03

(f) Ellenberg N scores	aggregate class								
	1	2	3	4	5	6	7	8	All
Temperature previous Summer	0.10	-0.44	0.13	-0.05	0.13	0.37	-0.30	0.21	0.19
Temperature Autumn	0.17	-0.55	0.05	-0.18	0.06	0.35	-0.52	0.01	0.19
Temperature Winter	0.59	0.15	-0.42	0.06	-0.05	0.06	-0.27	-0.24	0.01
Temperature Spring	0.33	0.25	-0.07	-0.13	-0.35	-0.45	0.40	-0.14	-0.30
Temperature survey Summer	-0.45	0.22	0.12	0.06	0.17	-0.26	0.36	0.20	0.05
100 mm Soil temp. previous Summer	0.05	-0.44	-0.19	-0.10	0.37	0.46	-0.61	0.21	0.20
100 mm Soil temp. Autumn	0.52	-0.18	0.13	0.12	0.10	0.31	-0.68	0.04	0.15
100 mm Soil temp. Winter	0.46	0.24	-0.46	0.07	-0.20	0.00	-0.64	-0.21	-0.16
100 mm Soil temp. Spring	0.26	0.25	-0.06	-0.07	-0.32	-0.34	0.24	-0.11	-0.36
100 mm Soil temp. survey Summer	-0.60	-0.01	-0.07	0.19	0.17	-0.01	0.21	-0.05	-0.01
Mean maximum temp. previous Summer	0.00	-0.41	0.20	-0.06	0.07	0.27	-0.20	0.27	0.12
Mean maximum temp. Autumn	0.19	-0.49	0.13	-0.23	0.05	0.28	-0.53	0.13	0.18
Mean maximum temp. Winter	0.61	0.16	-0.41	0.07	-0.03	0.09	-0.25	-0.21	0.04
Mean maximum temp. Spring	0.24	0.23	0.00	-0.12	-0.44	-0.42	0.38	-0.10	-0.33
Mean maximum temp. survey Summer	-0.68	0.22	0.09	0.07	0.39	-0.13	0.29	0.16	0.17
Mean minimum temp. previous Summer	0.41	-0.37	0.05	-0.07	0.15	0.61	-0.48	0.08	0.31
Mean minimum temp. Autumn	0.13	-0.53	0.03	-0.15	0.15	0.39	-0.51	-0.09	0.26
Mean minimum temp. Winter	0.60	0.10	-0.38	0.09	-0.08	0.11	-0.26	-0.26	0.02
Mean minimum temp. Spring	0.37	0.29	-0.11	-0.06	-0.21	-0.46	0.33	-0.20	-0.22
Mean minimum temp. survey Summer	0.24	0.10	0.16	0.06	-0.28	-0.43	0.52	0.27	-0.17
Rainfall previous Summer	0.67	0.22	-0.14	0.04	-0.18	0.15	-0.41	-0.29	-0.01
Rainfall Autumn	-0.54	-0.07	-0.46	0.05	0.14	0.10	-0.02	-0.34	0.12
Rainfall Winter	-0.40	-0.22	-0.10	0.13	0.51	0.22	0.00	-0.31	0.14
Rainfall Spring	0.60	-0.16	-0.47	-0.13	0.24	0.07	-0.60	-0.27	-0.04
Rainfall survey Summer	0.16	0.16	0.02	-0.02	-0.51	-0.41	0.17	0.08	-0.30

(g) Ellenberg R scores (same as Table 3.11)	aggregate class								
	1	2	3	4	5	6	7	8	All
Temperature previous Summer	-0.35	-0.14	0.12	0.16	0.21	0.50	-0.34	0.32	0.20
Temperature Autumn	-0.40	-0.12	-0.19	-0.03	0.12	0.34	-0.44	0.11	0.09
Temperature Winter	0.18	0.19	-0.63	0.05	0.02	0.06	0.12	-0.12	-0.03
Temperature Spring	0.34	0.23	-0.08	-0.16	-0.42	-0.29	0.42	-0.22	-0.16
Temperature survey Summer	-0.02	-0.06	0.58	-0.02	-0.08	0.00	-0.12	-0.07	-0.04
100 mm Soil temp. previous Summer	-0.42	-0.31	0.14	0.12	0.37	0.52	-0.45	0.43	0.13
100 mm Soil temp. Autumn	-0.45	0.04	-0.43	0.04	0.08	0.19	-0.42	0.29	-0.10
100 mm Soil temp. Winter	0.37	0.27	-0.65	0.10	-0.01	0.05	-0.13	0.05	-0.06
100 mm Soil temp. Spring	0.46	0.19	-0.25	-0.10	-0.27	-0.12	0.31	-0.12	-0.16
100 mm Soil temp. survey Summer	0.17	-0.34	0.03	0.03	0.05	0.09	-0.05	-0.27	-0.11
Mean maximum temp. previous Summer	-0.28	-0.17	0.27	0.12	0.12	0.45	-0.32	0.33	0.19
Mean maximum temp. Autumn	-0.36	-0.04	-0.14	-0.03	0.09	0.30	-0.50	0.24	0.04
Mean maximum temp. Winter	0.13	0.20	-0.63	0.05	0.03	0.03	0.18	-0.09	-0.02
Mean maximum temp. Spring	0.45	0.20	0.01	-0.13	-0.50	-0.22	0.36	-0.18	-0.13
Mean maximum temp. survey Summer	-0.11	-0.08	0.52	0.01	0.22	-0.05	-0.23	-0.10	0.04
Mean minimum temp. previous Summer	-0.31	0.03	-0.25	0.16	0.27	0.41	-0.26	0.28	0.16
Mean minimum temp. Autumn	-0.53	-0.14	-0.24	-0.03	0.20	0.33	-0.40	0.02	0.15
Mean minimum temp. Winter	0.20	0.15	-0.65	0.10	-0.01	0.17	0.11	-0.13	-0.01
Mean minimum temp. Spring	0.18	0.28	-0.23	-0.11	-0.25	-0.34	0.46	-0.25	-0.20
Mean minimum temp. survey Summer	0.14	0.03	0.41	-0.04	-0.49	0.19	0.25	0.09	-0.08
Rainfall previous Summer	0.26	0.30	-0.55	0.05	-0.11	-0.23	0.00	-0.14	-0.02
Rainfall Autumn	0.41	-0.30	-0.33	0.05	0.31	-0.14	-0.43	-0.42	-0.03
Rainfall Winter	0.15	-0.47	-0.14	0.08	0.56	0.24	-0.36	-0.19	0.00
Rainfall Spring	-0.17	-0.06	-0.44	-0.17	0.29	-0.21	-0.13	0.00	-0.10
Rainfall survey Summer	-0.01	0.20	-0.09	-0.02	-0.56	0.32	0.39	0.09	-0.16

(h) Ellenberg W scores	aggregate class								
	1	2	3	4	5	6	7	8	All
Temperature previous Summer	-0.43	-0.15	-0.17	0.10	-0.28	-0.08	0.08	0.20	-0.11
Temperature Autumn	-0.22	-0.10	-0.39	-0.02	-0.16	0.08	-0.10	-0.03	-0.25
Temperature Winter	0.12	-0.12	-0.01	-0.07	0.44	-0.15	0.50	-0.10	-0.18
Temperature Spring	0.19	0.23	-0.25	-0.40	0.26	0.10	0.23	-0.09	0.04
Temperature survey Summer	0.66	0.32	0.20	-0.17	-0.28	0.13	0.05	-0.20	0.28
100 mm Soil temp. previous Summer	-0.37	0.08	0.34	0.21	-0.17	-0.22	0.25	0.03	0.17
100 mm Soil temp. Autumn	-0.29	-0.54	-0.05	0.28	0.28	-0.33	0.17	-0.12	-0.12
100 mm Soil temp. Winter	-0.20	-0.15	-0.05	-0.09	0.36	-0.17	0.58	-0.06	-0.25
100 mm Soil temp. Spring	0.17	0.28	-0.21	-0.36	0.24	0.18	0.39	0.04	0.12
100 mm Soil temp. survey Summer	0.47	0.32	-0.12	0.01	-0.46	0.23	0.47	0.06	0.36
Mean maximum temp. previous Summer	-0.48	-0.07	-0.16	0.08	-0.36	-0.05	-0.04	0.11	-0.05
Mean maximum temp. Autumn	-0.33	-0.12	-0.40	-0.08	-0.04	0.09	-0.05	0.19	-0.21
Mean maximum temp. Winter	0.13	-0.09	0.04	-0.06	0.46	-0.16	0.49	-0.05	-0.18
Mean maximum temp. Spring	0.08	0.28	-0.22	-0.38	0.09	0.13	0.28	-0.11	0.09
Mean maximum temp. survey Summer	0.47	0.20	0.22	-0.04	-0.44	0.02	-0.01	-0.20	0.19
Mean minimum temp. previous Summer	-0.40	-0.27	-0.20	0.10	0.02	-0.12	0.27	0.47	-0.27
Mean minimum temp. Autumn	0.03	-0.13	-0.37	0.03	-0.18	0.03	-0.08	-0.18	-0.28
Mean minimum temp. Winter	0.04	-0.16	-0.09	-0.05	0.41	-0.16	0.48	-0.12	-0.21
Mean minimum temp. Spring	0.37	0.11	-0.29	-0.37	0.48	0.02	0.10	-0.02	-0.08
Mean minimum temp. survey Summer	0.62	0.32	0.06	-0.36	-0.01	0.32	0.15	-0.13	0.37
Rainfall previous Summer	-0.20	-0.14	0.03	0.12	0.47	-0.12	0.22	0.11	-0.12
Rainfall Autumn	0.19	0.11	0.37	0.05	-0.16	0.30	0.33	0.21	0.03
Rainfall Winter	0.54	0.09	0.23	0.31	0.14	-0.10	0.55	0.07	0.28
Rainfall Spring	0.09	-0.18	-0.05	0.18	0.49	0.07	0.05	0.12	-0.01
Rainfall survey Summer	0.69	0.21	-0.34	-0.42	0.23	0.10	0.53	0.00	0.28