Question 13: What are the possible causes of more overgrown streamside vegetation? What are the implications for other species groups and associated freshwater habitats?

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DEFINITIONS

- 'River Habitats Survey' – This was included in the Countryside Survey for the first time in 1998. It is a standard assessment procedure for evaluating the physical structure of the watercourse.
- 'watercourse types' – these may be defined by categorisation of the data or taken from existing definitions such as those in the River Habitats Survey.
- 'vegetation groups' – these may be taken from the existing Countryside Vegetation Systems used in CS2000 or may be specifically defined for the question.

POLICY CONTEXT STATEMENT

1. The changes in streamside vegetation were among the strongest shown by any of the vegetation plots recorded in CS2000 (Haines-Young *et al.* 2000). The lowland areas of England, Wales and Scotland showed the most significant changes. The results indicate that there were significant decreases in the mean numbers of species in streamside plots, aligned with increases in both the proportion of competitive species and the fertility score of the species in the plots. These changes may be seen as decreases in habitat quality, especially in the light of results from analyses of the CS1990 vegetation during the ECOFACT programme (Bunce *et al.* 1999). These analyses showed that for a range of indicator species for unimproved grassland (supplied by English Nature), acidic and mesotrophic grassland indicators were recorded in a greater proportion of streamside plots than any other plot type. It was concluded that streamsides formed important refugia for these indicator species in lowlands, providing unique areas within the lowlands where these grassland types are able to persist. Similarly work in farming landscapes of southern Quebec (Boutin, Jobin & Bélanger 2003) concluded that whilst no plants of special conservation importance were located in riparian habitats, they deserved special protection in intensive arable areas because they harbour a suite of wetland plants not found in other farmland habitats. However, plants are not the only group for which the riverine habitat is important and there may be conflicts between the requirements for plant species and those for other species which use streamsides (e.g. otters, watervoles, invertebrate, myxomycete and bird species).

2. Currently the management of land adjacent to streams and rivers is largely carried out by the individual land owner whose land the watercourse runs through. The Environment Agency (EA) has responsibility for the

watercourses themselves and for the potential impacts on wildlife of processes such as land drainage or creation of flood defences. The EA also have responsibility as lead organisation for 39 species and 5 habitats of wetland character under the UK BAP. Currently their efforts are largely targeted towards Priority habitats and species and they have rather less influence upon the general condition of habitats adjacent to streams and rivers except in an advisory capacity, e.g. advising on mowing times etc. The introduction of the Water Framework Directive (WFD) which is the most substantial piece of EC water legislation to date, requiring all inland and coastal waters to reach good status by 2015, will have a substantial impact on the water environment. The WFD is currently being translated into law by member states. Legislation will be designed to improve the water environment in the context of a broader water related environment, building upon the development of solutions at a catchment scale. One of the key features of the directive is the introduction of a new definition of water status concerned with the ecological health of surface water as well as its chemical composition. The Environment Agency will be given a central role in implementing the Directive, including new duties to co-ordinate the production of river basin management plans. Once in place it will have a substantial impact on the way in which riparian habitats are both monitored and managed.

3. Whilst the WFD may influence both the streamsides and the watercourses of the future, this question seeks to understand more about the changes in streamside habitats during the period 1990-1998 as well as the potential causes of change. A number of key organisations providing advice to landowners may have had an impact on the way in which streamside habitats were managed between the period of CS1990 and CS2000. Both the Department for the Environment, Food and Rural Affairs (DEFRA) as part of their Countryside Stewardship Scheme and the Farming and Wildlife Advisory Group (FWAG) encourage the creation of buffer strips of at least 1m width adjacent to watercourses. The objectives of the Water Fringe Areas option of the former MAFF funded Habitat scheme include the enhancement of the wildlife conservation value of watercourse banksides and contribution to an improvement in water quality by creating buffer strips or extensive grazing management of land adjacent to watercourses. The EA carried out research during this period to investigate the role of buffer strips (Environment Agency 1996) as a means of reducing sediment, fertiliser and pesticide inputs, and also recommend the use of vegetation in buffer strips to settle sediment before any runoff enters watercourses or runs onto highways. Their research also found that mature buffer strips may provide a valuable habitat for sustaining and allowing migration of freshwater and terrestrial wildlife. In addition, whilst there is no policy within the EA as regards riparian fencing, it has been and continues to be generally viewed as good-practice in areas of accelerated bankside erosion with reductions in fisheries (salmonid) populations, or where there are severe diffuse pollution issues within sub-catchments, which may have resulted in an increase in fenced watercourses in some areas.

4. In parallel with general encouragement towards the creation of buffer strips, data collected as part of both CS1990 and CS2000 indicated that there was a marked improvement in the biological condition of watercourses in the survey

squares during this period (Furse *et al.* 2002). These findings supported the findings of an earlier national study carried out between 1990 and 1995 (Clarke, Furse & Davy-Bowker 1999) which were accompanied by an improvement in the chemical grade of rivers in England and Wales and a sharp decrease in pollutant load (EA web-site). Of the factors contributing to the biological improvements measured within CS2000, an increase in the prevalence of buffer strips along watercourses managed separately from adjacent fields was considered as potentially important.

5. This question looks more closely at the dynamics of vegetation in the streamside plots over the period 1990 -1998 to seek to identify whether changes in vegetation reflect changing management and to investigate both the relationship between streamside vegetation and streamside quality as well as the relationship between streamside vegetation and vegetation in the wider countryside. It investigates whether perceived and actual ecological gains from development of woody riparian buffer strips may conflict with a loss of habitat which provides a refugia for plant species and species assemblages threatened in the wider countryside.

6. There is a need to define habitat and conservation objectives in the riparian zone so that appropriate management regimes can be developed. Such objectives will need to balance the different ecological functions of the riparian zone in the context of the wider countryside and the different species for which it is important.

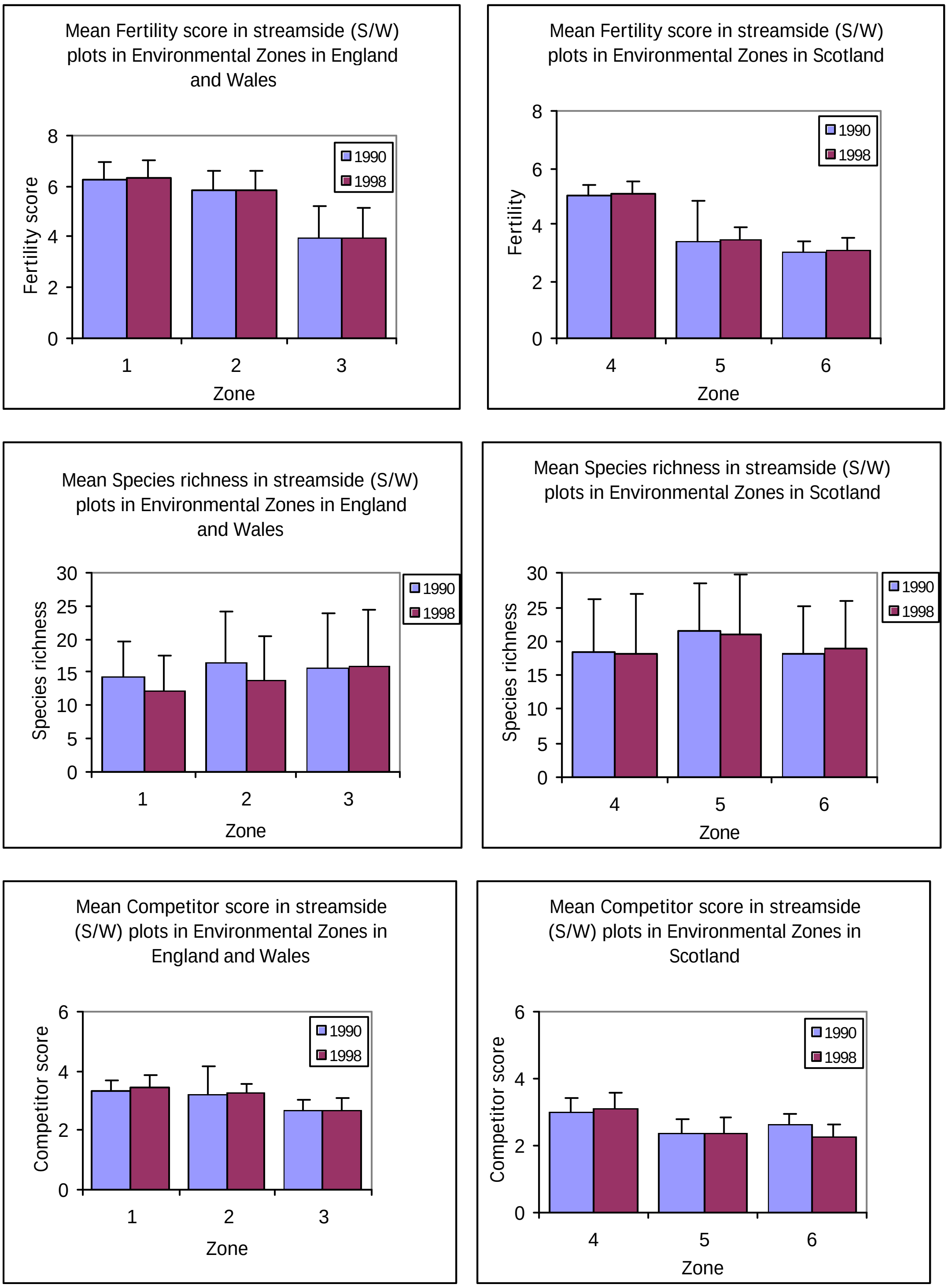
Background

The results shown in Fig 13.1 and Table 13.1 published for CS2000 (Haines-Young *et al.* 2000) provide the background to this question. Indications of a strong downward trend in the quality of vegetation recorded in streamside plots warranted further investigation to discover both, more about the changes themselves, as well as the possibility of identifying potential causes of change.

Table 13.1 Significant changes in condition measures for streamside plots 1990-1998 (non-significant results are not included).

Zone	*Condition measure*	*Mean score 1990*	*Mean score 1998*	*No of plots*	*Direction and significance*
1	Species richness	14.16	12.13	396	DOWN***
2	Species richness	16.19	13.67	443	DOWN***
1	Fertility score	6.19	6.29	396	UP***
2	Fertility score	5.73	5.79	442	UP*
4	Fertility score	4.98	5.07	236	UP**
5	Fertility score	3.32	3.38	268	UP**
1	Competitor score	3.35	3.47	396	UP***
2	Competitor score	3.14	3.23	440	UP***
4	Competitor score	3.00	3.08	236	UP***
1	Ruderal score	2.44	2.30	396	DOWN***
2	Ruderal score	2.48	2.31	440	DOWN***
3	Ruderal score	2.17	2.13	224	DOWN*
4	Ruderal score	2.50	2.42	236	DOWN**
2	Stress score	1.97	2.03	440	UP**
6	Stress score	3.42	3.38	256	DOWN*
1	Light score	6.62	6.58	396	DOWN**
2	Light score	6.45	6.31	442	DOWN***
5	Moisture score	6.70	6.65	268	DOWN*
1	Soil pH	6.51	6.57	396	UP***
4	Soil pH	5.59	5.64	236	UP**
5	Soil pH	4.44	4.50	268	UP**
6	Soil pH	3.95	4.02	257	UP*

Fig 13.1 Changes in condition measures in streamside (S/W) plots in Great Britain 1990-1998



7. These results indicate that there has been a shift in the vegetation associated with streamsides towards more competitive, tall growing vegetation resulting in a decrease in species richness.

SCIENCE OUTPUTS

Approach

8. Data checking was carried out to investigate plots where there were significant increases and decreases in species richness and fertility scores. This was done by going back to the Field Assessment Books (FAB's) (Barr 1998) and extracting photographs for a number of plots with the highest and lowest values for species richness and fertility. These were studied to identify whether there were any obvious causes for changes observed, and whether the changes observed were apparent from the photograph. Spatial data sheets were also looked at to check whether new fences had been put up in the vicinity of the stream.

9. Re-analysis of data using updated programmes was carried out. For the CS2000 report paired t tests with an additional random factor to account for the effect of square (i.e. to avoid pseudo replication from plots being in the same square) were used to detect significant changes in condition measures. We used a General Linear Model (SAS institute 1999-2001) which is a more robust and flexible method to account for variation. An additional random factor was included as previously. The null hypothesis tested whether there was a significant difference between the data and zero. We tested the hypothesis that there was no change by looking at the effect of Environmental zone, then aggregate class and then aggregate class within Environmental zone.

10. Analysis of the data for streamside plots was looked at in more detail in order to identify where the declines in habitat quality, in particular, species richness, were taking place and also to look more closely at which species were being lost and gained. Species gains were looked at both in terms of increases in occurrence as well as increases in the % cover of particular species.

11. Attempts were made to try to identify whether streamsides may be refugia for certain plant species. This was looked at in two ways, concentrating on different species groups. The first involved looking at Indicator species of mesotrophic and acidic grasslands taken from a list provided by English Nature. The occurrence of these species in streamside plots was compared to their distribution in other plot types. This included looking at changes in distribution between 1990 and 1998 and whether declines or increases were more significant in streamside plots compared to other plot types.
12. The second involved looking closely at the decreasing species in streamside plots to identify species which may be reliant on the conditions particular to waterside habitats. The species selected on that basis were then looked at in terms of their occurrence in different plot types relative to their occurrences in streamside plots in an attempt to identify whether streamside areas were acting as refugia for these species.

13. Data for the watercourses associated with the streamside vegetation plots (collected for Module 2 of Countryside Survey) was integrated with the vegetation data to try to identify relationships between water quality and

vegetation quality, i.e. are overgrown streamsides related to good biological quality of adjacent streams? Based on the hypothesis that biological condition of the watercourse is related to the condition of the vegetation adjacent to it, regression analysis was used to investigate how indicators of water quality varied alongside indicators of vegetation condition in both 1990 and 1998. It was also possible to look at how change (1990-1998) in vegetation condition was related to change in water quality across the same period

14. Data on the management of land adjacent to watercourses (River Habitats Survey data and spatial CS data) was investigated in an attempt to try and identify possible causes of the observed changes in vegetation. RHS produces indicators of the quality and extent of modification of the river corridor and, as with indicators of biological condition, it was possible to investigate relationships through regression, based on the hypothesis that the condition of vegetation on streamsides is likely to be dependent on the quality and extent of modification of the river corridor.

15. As part of module 1 a 20m riparian strip was created, within GIS, for each stream subject to a RHS, to provide information on the Broad Habitats for the RHS area. This data was used to investigate whether the condition measures for the vegetation in streamside plots differed according to the predominant Broad Habitat (the one making up the highest % land) of the riparian strip.

16. In order to identify whether fencing off of streamsides was a cause of the observed changes in vegetation, buffers of 5 and 10m around each streamside plot were created. The presence of fences in the buffer zone for each plot in 1990 and 1998 and any changes over the time period were recorded.

17. Approaches were made to the major bodies with some involvement in the management of streamsides (EA, DEFRA, and English Nature) for information on policy relating to management of streamside habitats and species. As it has not been possible to convene a workshop where all parties were present, this has been done through contact with individuals.

Data Checking

18. Analysis of photographs for the plots at which there were significant changes in either species richness or fertility indicated that these changes were probably the result of a range of different factors. It was apparent that for some plots changes were likely to have been caused by alterations in grazing regimes, either a change in stocking density or in livestock type. For one plot it was clear that the incursion of a sand dune had had a significant impact on species richness, for others the photographs were unable to provide any information on changes. There were no clear patterns for fences located alongside streams. Where fences were present, they had been present in both 1990 and 1998. In many cases there were no fences located anywhere near the plots.

19. The reanalysis of data using updated programmes showed that the direction of change in terms of increasing fertility and decreasing species richness was as reported (Appendix 1, Tables 13.24, 13.25 and 13.26). There were some differences due to alterations in the statistical procedure used which resulted in changes to the significance levels of some of the results. Nitrogen scores did not change much, there were still significant increases in zones, 1,4 and 5 and aggregate classes 3,4,6,7,and 8. There was no longer a significant increase in zone 2 or aggregate class 2 but these had only been small increases and have changed due to differences in calculation of significance. In addition there was found to be a significant increase in zone 6 and a decrease in aggregate class 5. The analyses by aggregate class within environmental zone were quite different, there were only significant results in zone 4, and aggregate class 4 and zone 5 aggregate class 6 whereas previously there had been many more significant results. The light scores showed additional significant results, which were mostly decreases in score across Environmental zones and aggregate classes although there was an increase in light score in zone 6 and aggregate class 8. There were significant decreases in zones 2,3,4,5 and aggregate classes 3,4,5,6,7. The by aggregate class within environmental zone analyses showed many more significant results than previously and demonstrate that there have been significant reductions in the number of light loving species which would fit with the pattern of increasing rankness and overgrown streamsides. There were also more significant moisture scores detected. Moisture scores were decreasing in zones 1,3,4,5,6, aggregate classes 2,5,6,7,8 and increasing in aggregate class 4. There were also more significant results from the by aggregate class, within zone analyses, these were mostly decreases but there were some increases. The overall pattern here suggests that many streamsides have been getting drier which might be associated with increases in competitive species and loss of wetland species. Streamsides in infertile grassland may have been getting wetter. It is interesting that the scores for soil pH did not change with the reanalysis. They were still increasing in zones 1,4,5,6, aggregate classes 2,4,7,8 and in aggregate class 8 within zone 5.

Further analysis of the data for streamside plots

Watercourse type

20. The data was categorised into watercourse type using information taken from the original plot recording sheet. Thus watercourse types were categorised into; stream, canal, river, other, other ditch and roadside ditch. The majority of the plots were streamside and there were low numbers in some of the categories (Table 13.2).

Table 13.2 shows the number of plots in each watercourse type for the change analysis using 1990-1998 replicates.

Watercourse type	Number of plots
Canal	14
River	199
Stream	1192
Road ditch	68
Other ditch	481
Other	40

21. There were significant differences in condition measure between the different watercourse types (Table 13.3), streamside plots had a higher mean species diversity (17.1) and lower nitrogen score (4.4) than canal plots (mean species diversity 11.8, mean N score 6.3), the Ellenberg moisture scores show that road ditches are significantly drier than other plot types, the light scores show that there are lower light levels on streams and rivers. However, analyses of change showed that many of the changes were of similar direction and magnitude. If this approach is to be continued then it would be desirable to obtain more detailed and accurate information regarding the watercourse type than is currently the case.

Table 13.3 shows the results from one way ANOVA's looking at differences in condition measure between watercourse types.

	F	*Sig.*
Species richness 1990	8.16	***
Species richness 1998	22.70	***
Change in species richness	2.29	*
Ellenberg Nitrogen score 1990	54.11	***
Ellenberg Nitrogen score 1998	80.59	***
Change in Ellenberg Nitrogen score	2.93	*
Ellenberg pH score 1990	58.33	***
Ellenberg pH score 1998	86.77	***
Change in Ellenberg pH score	2.48	*
Ellenberg Moisture score 1990	21.51	***
Ellenberg Moisture score 1998	34.87	***
Change in Ellenberg Moisture score	3.91	***
Ellenberg Light score 1990	5.21	***
Ellenberg Light score 1998	4.03	***
Change in Ellenberg Light score	0.54	n.s.

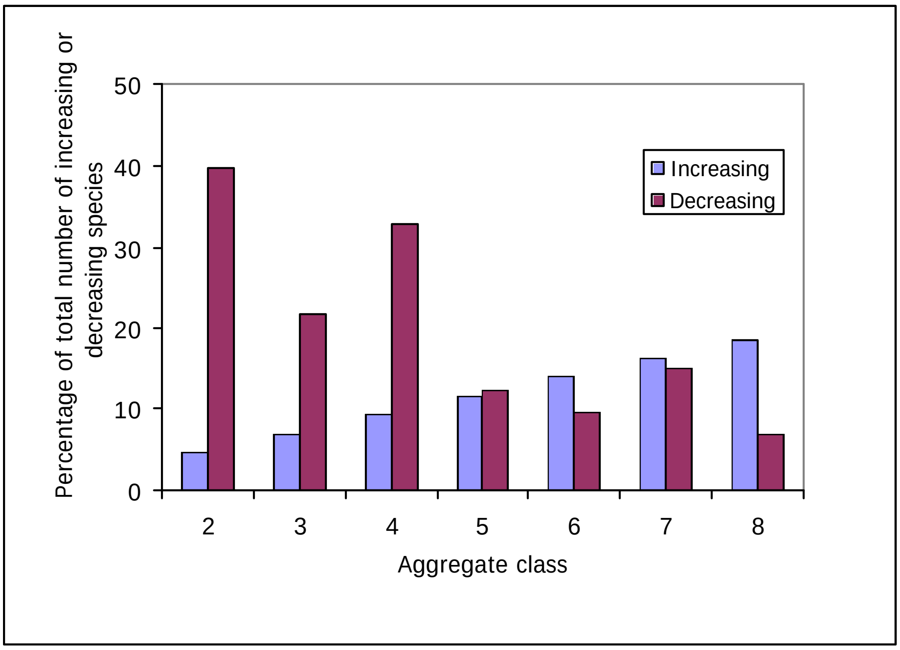
Changes in individual species

22. Changes in individual species were looked at alongside changes in the aggregate classes assigned to streamside plots. The total number of species which showed a significant increase in streamside plots assigned to at least one aggregate class was 43, of these species 6 showed significant increases in 2 aggregate classes and one, *Solanum dulcamara*, a woody perennial, in 3 aggregate classes. In contrast the number of species which showed a

significant decrease in streamside plots assigned to at least one aggregate class was 73, of these species 19 showed significant decreases in 2 aggregate classes, 3 species (*Plantago major*, *Stellaria media* and *Lysimachea nemorum*) showed significant decreases in 3 aggregate classes and 1, *Agrostis stolonifera* significantly decreased in 4 aggregate classes.

23. Fig 13.2 presents a basic analysis of the data on the numbers of species which either increased or decreased between 1990 and 1998 and shows for each aggregate class how the number of increasing or decreasing species in that aggregate class related to the total numbers of increasing and decreasing species. It shows that species which increased between 1990 and 1998 were predominantly from either woodland or upland aggregate classes (5-8). Conversely species which decreased over the same period were associated with grassland vegetation types (2-4).

Fig 13.2 The percentage of total numbers of increasing and decreasing species within each aggregate class between 1990 and 1998.

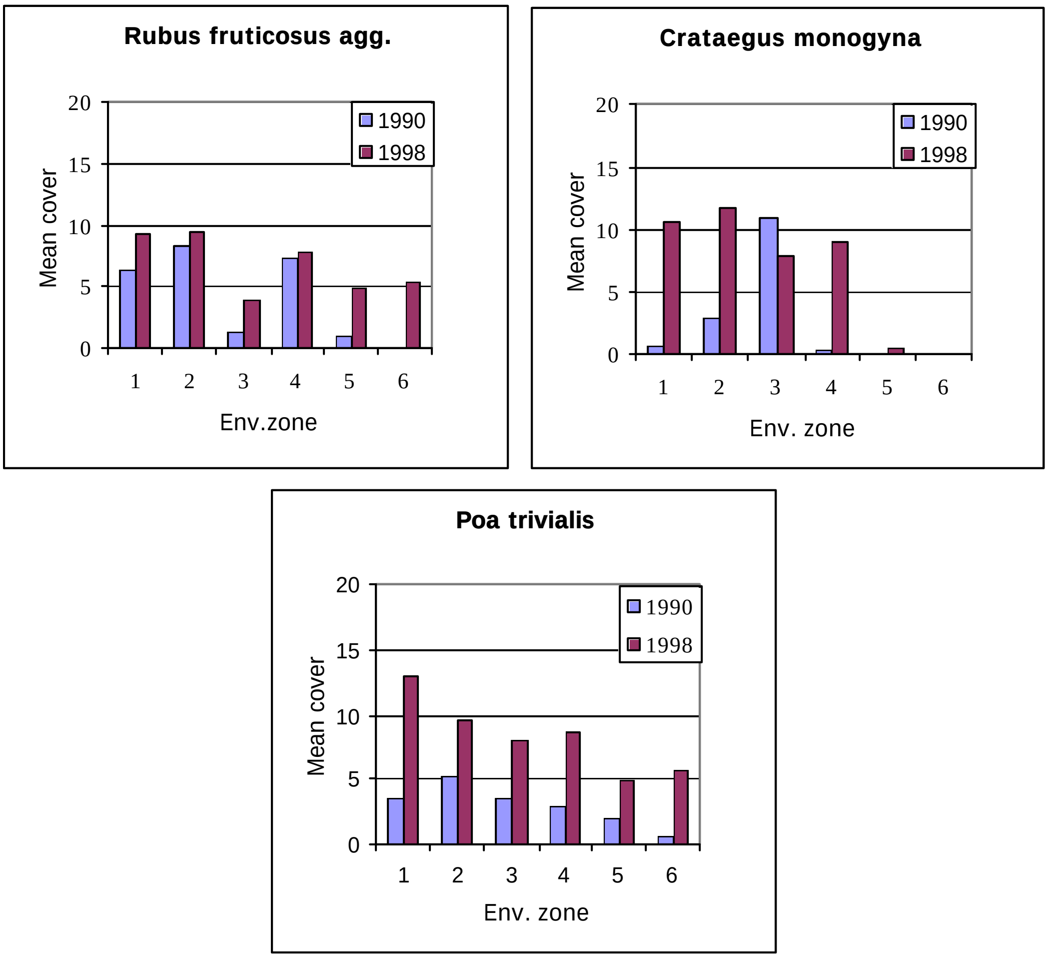


24. A large number of the decreasing species in streamside plots are species which are both common and widespread in different habitats (e.g. *Agrostis stolonifera*, *Cirsium arvense*, *Plantago major*, *Cerastium fontanum*). It is the species which are either less common or widespread in the general landscape and those which are reliant on moist streamside conditions which are of concern.

25. Previously, species increases were detected by increases in the number of occurrences in plots. A number of the species which have shown increases in occurrence in streamside plots are either competitive or woody late-successional species. For this type of vegetation, it is also important to determine how the % cover of these species has changed within plots as it can have a significant impact on other less competitive, light demanding species. *Rubus fruticosus* agg. , *Poa trivialis*, and *Crataegus monogyna* both showed a

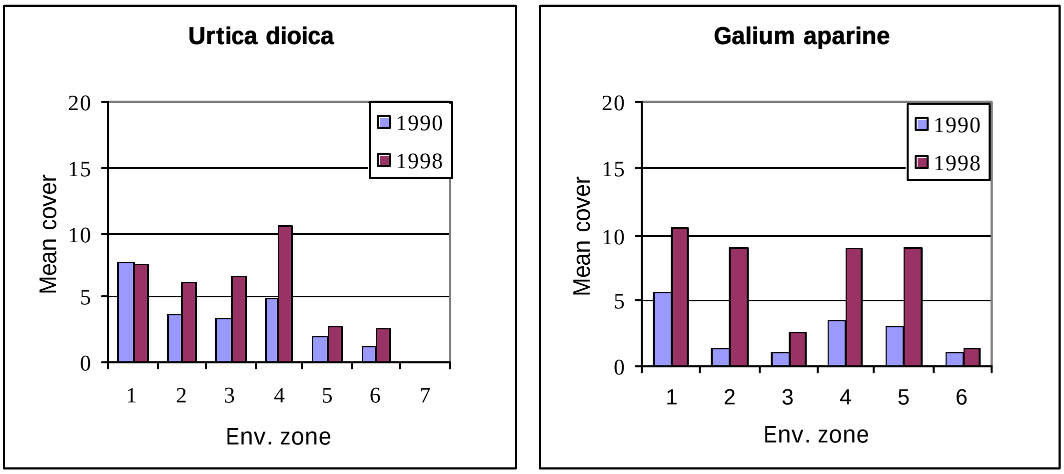
significant increase in the number of plots in which they were present in aggregate class IV, their % cover within these plots also increased (Figs 13.3 a), b) and c)). So as well as increasing in distribution across plots these species are also impacting upon other species by increasing their abundance within plots.

Figure 13.3 a) Mean % cover of *Crataegus monogyna* in streamside plots in Aggregate class IV in 1990 and 1998, b) Mean % cover of *Rubus fruticosus* agg. in streamside plots in Aggregate class IV in 1990 and 1998 and c.) Mean % cover of *Poa trivialis*. in streamside plots in Aggregate class IV in 1990 and 1998.



26. Even if the number of plots containing the species does not increase, changes in cover amongst certain species in a plot may still assist in explaining observed changes in condition measures such as increased nitrogen score, competitive score and decreased species richness. Examples of species which may be playing a significant role are *Urtica dioica* and *Galium aparine* (Fig. 13.4). These are competitive species which are commonly associated with streamsides and have a tendency to form dense stands.

Figure 13.4 a) Mean % cover of *Urtica dioica* in streamside plots in Aggregate class IV in 1990 and 1998, b) Mean % cover of *Galium aparine* agg. in streamside plots in Aggregate class IV in 1990 and 1998.



Changes in Ellenberg scores weighted using percentage cover

27. The Ellenberg scores were weighted to take % cover of each species recorded into account. Analyses were carried out using the same method that was used to repeat the analysis for Ellenberg scores. These were done by Environmental zone (Table 13.4), aggregate class (Table 13.5) and aggregate class within Environmental zone (Table13.6). The cover weighted Ellenberg pH scores were different to the unweighted scores, the increases in pH score detected in zones 1, 4, 5, and 6 and aggregate classes 2, 4, 7 and 8 in the unweighted scores were no longer significant which suggests that the species with high pH scores that are increasing are not species which provide a lot of cover within the plot. Moisture scores did not differ greatly from the unweighted Ellenbergs (Appendix 1). The by aggregate class within Environmental zone analysis did not show as many significant results in the cover weighted analysis. The cover weighted light scores were similar to the unweighted with a decrease in zones 3,4 and 5 suggesting increased shading and loss of light loving species. There was an increase in zone 6 indicating the opposite. There was no longer a significant decrease in light score in region 2.

28. There were greater differences between cover weighted and non-cover weighted nitrogen scores. Nitrogen score no longer increased significantly in Environmental Zones 4, 5 and 6 or aggregate classes 4, 6, 7 and 8. This was a surprising result as it was generally believed that cover-weighted Ellenberg values would be more sensitive to detecting changes in nitrogen score than ordinary Ellenberg values. There was a significant increase in Environmental zone 2 which had been significant in the original analysis for module 1 but was not significant in the unweighted reanalysis. This suggests that there has been an increase in nitrogen score here but it is relatively small, using cover weighted scores puts in an additional factor demonstrating that it is having a significant effect. Overall although there is a general trend towards an increase in cover of species with a high nitrogen score there is a great deal of variability in the % cover scores which prevents them from being statistically significant.

Table 13.4 shows the significant results for cover-weighted Ellenberg values by Environmental zone.

Variable	Env. zone	N	Mean 1990	Mean 1998	Std Dev 1990	Std Dev 1998	Diff	Direction	sigcov weight
Fertility score (N)	1	394	6.37	6.45	0.81	0.79	0.09	+	*
Fertility score (N)	2	442	5.85	5.92	0.89	0.89	0.08	+	*
Light score (L)	3	223	6.60	6.51	0.66	0.74	-0.09	-	***
Light score (L)	4	236	6.69	6.58	0.60	0.73	-0.10	-	***
Light score (L)	5	268	7.00	6.96	0.46	0.50	-0.03	-	***
Light score (L)	6	257	6.88	6.91	0.42	0.47	0.03	+	***
Moisture score (W)	1	394	6.14	6.13	0.86	0.90	-0.01	-	***
Moisture score (W)	3	223	6.48	6.46	0.64	0.64	-0.02	-	***
Moisture score (W)	4	236	6.39	6.37	0.83	0.84	-0.02	-	***
Moisture score (W)	5	268	6.66	6.61	0.77	0.78	-0.05	-	***
Moisture score (W)	6	257	6.61	6.64	0.66	0.61	0.03	+	***

Table 13.5 shows the significant results for cover-weighted Ellenberg values by Aggregate class

Variable	Agg. class	N	Mean 1990	Mean 1998	Std Dev 1990	Std Dev 1998	Diff	Direction	sigcov weight
Fertility score (N)	2	459	6.49	6.59	0.65	0.62	0.10	+	**
Fertility score (N)	3	118	5.88	6.05	0.50	0.65	0.16	+	**
Light score (L)	3	118	7.12	6.97	0.38	0.43	-0.15	-	***
Light score (L)	4	352	6.83	6.77	0.38	0.45	-0.07	-	***
Light score (L)	5	129	5.29	5.14	0.66	0.77	-0.14	-	***
Light score (L)	6	201	5.95	5.73	0.72	0.83	-0.23	-	***
Light score (L)	7	389	6.91	6.90	0.26	0.32	-0.01	-	***
Light score (L)	8	171	7.26	7.25	0.29	0.30	-0.01	-	***
Moisture score (W)	2	459	6.23	6.13	0.90	0.90	-0.09	-	***
Moisture score (W)	4	352	6.32	6.37	0.69	0.71	0.05	+	***
Moisture score (W)	5	129	5.78	5.74	0.54	0.65	-0.04	-	***
Moisture score (W)	6	201	6.32	6.21	0.74	0.74	-0.11	-	***
Moisture score (W)	7	389	6.62	6.62	0.58	0.61	0.00	-	***
Moisture score (W)	8	171	7.28	7.14	0.67	0.66	-0.14	-	***

Table 13.6 shows the significant results for cover-weighted Ellenberg values by Aggregate class within Environmental zone.

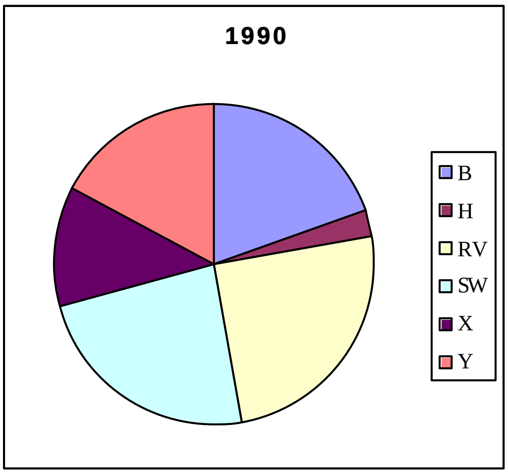
Variable	Env. zone	Agg. class	N	Mean 1990	Mean 1998	Std Dev 1990	Std Dev 1998	Diff	Direction	sigcovw eight
Fertility score (N)	1	2	259	6.62	6.71	0.61	0.57	0.09	+	*
Fertility score (N)	1	3	37	5.95	6.18	0.59	0.58	0.23	+	*
Fertility score (N)	4	2	46	6.15	6.38	0.73	0.65	0.23	+	*
Light score (L)	1	5	42	5.51	5.47	0.64	0.86	-0.04	-	***
Light score (L)	2	2	146	6.66	6.49	0.40	0.62	-0.17	-	*
Light score (L)	2	4	92	6.86	6.77	0.27	0.38	-0.09	-	***
Light score (L)	2	5	77	5.19	5.02	0.65	0.67	-0.17	-	***
Light score (L)	2	6	69	5.92	5.57	0.79	0.88	-0.35	-	***
Light score (L)	2	7	4	7.06	7.11	0.31	0.21	0.05	+	*
Light score (L)	2	8	2	7.06	7.04	0.04	0.02	-0.02	-	**
Light score (L)	3	4	49	6.71	6.56	0.42	0.57	-0.15	-	***
Light score (L)	3	6	44	5.83	5.72	0.56	0.67	-0.11	-	***
Light score (L)	3	7	88	6.86	6.84	0.21	0.23	-0.01	-	***
Light score (L)	3	8	26	7.19	7.08	0.34	0.31	-0.10	-	***
Light score (L)	4	4	97	6.82	6.77	0.36	0.42	-0.04	-	***
Light score (L)	4	7	27	7.00	6.94	0.33	0.42	-0.06	-	***
Light score (L)	4	8	11	7.33	7.32	0.23	0.27	-0.02	-	***
Light score (L)	5	4	46	6.94	6.96	0.42	0.48	0.02	+	***
Light score (L)	5	6	23	6.22	6.34	0.69	0.54	0.12	+	***
Light score (L)	5	7	122	6.99	6.91	0.26	0.40	-0.08	-	***
Light score (L)	5	8	65	7.35	7.31	0.27	0.29	-0.05	-	***
Moisture score (W)	1	2	259	6.17	6.09	0.91	0.90	-0.01	-	***
pH score (R)	1	2	259	6.73	6.78	0.36	0.32	-0.03	+	*
pH score (R)	1	3	37	6.32	6.51	0.38	0.40	0.02	+	**

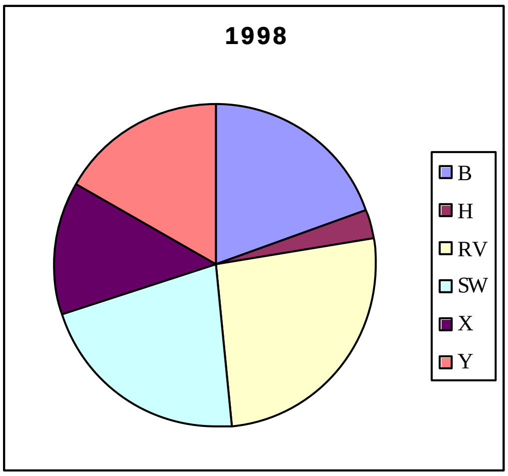
Streamsides as refugia

Habitats

29. The most significant changes in condition were noted in aggregate class IV, infertile grassland. As well as providing refugia for individual species it could also be argued that streamsides provide refugia for particular habitats. The number of plots in aggregate class IV in 1990 and 1998 were examined to see whether the distribution of aggregate class IV was changing in the landscape. It is apparent that the numbers of different plot types in aggregate class 4 are very similar for 1990 and 1998 (Fig 13.5). Infertile grassland appears to be slightly more frequent in streamside plots and roadside verges. Its' distribution is not changing within the landscape which indicates that if streamsides are acting as a refugia for this habitat type this is not changing at the present time. This does not mean that the quality of this habitat remains unchanged so subsequent work focused on individual species.

Fig. 13.5. The frequency of different plot types in aggregate class IV in 1990 and 1998.





Grassland indicators

Mesotrophic grassland indicators

30. In 1990, mesotrophic grassland indicator species (taken from a list provided by English Nature) were recorded from a significantly greater proportion of streamside plots than any other plot type (Bunce *et al.*1999). Mesotrophic indicator species are still found in greater proportions in streamside plots in many aggregate classes (3, 4, 6 and 7) in the 1998 data (Tables 13.7 and 13.8).

Table 13.7 Analysis of occurrence of unimproved mesotrophic grassland indicator species in 1998 by plot type and aggregate class using 1990-1998 replicates. The counts are the total number of species occurrences.

Aggregate class	*Total*	*Boundary*	*Hedge*	*Roadside verge*	*Streamside*	*Main*	*Habitat*
1	29	2		3		23	1
2	645	117	56	199	165	32	76
3	634	87	1	261	112	91	82
4	4484	364	51	698	1182	916	1273
5	392	55	60	21	92	61	103
6	1436	94	9	102	587	325	319
7	6541	325		390	2753	1519	1554
8	3878			33	1021	1759	999

Table 13.8 ;The percentage of plots in 1998 containing at least one mesotrophic indicator species. (The % is calculated by dividing the number of plots containing an indicator by the number of plots in that category in 1998)

Aggregate class	*Boundary*	*Hedge*	*Roadside verge*	*Streamside*	*Main*	*Habitat*
1	5.9		7.1		3.8	4.0
2	16.6	26.6	24.6	25.4	39.6	18.8
3	29.2	25.0	28.4	44.2	15.1	30.6
4	53.0	61.0	70.5	81.1	62.8	72.1
5	16.1	15.3	50.0	38.8	55.2	36.4
6	62.0	42.9	76.6	78.3	69.7	65.2
7	82.2		85.7	96.4	93.9	87.2
8	93.3		56.3	88.3	83.4	76.6

31. Over all the plot types mesotrophic indicator species were decreasing significantly in aggregate classes 4,6 and 7 between 1978 and 1990 (Table 13.9), they are still decreasing in aggregate classes 4 and 6 between 1990 and 1998 (Table 13.11) but are also decreasing in aggregate class 2. They are still decreasing in aggregate class 7, however, not enough to be statistically significant. The pattern in streamside plots was slightly different between 1978 and 1990 (Table 13.10), although mesotrophic indicators were decreasing in aggregate classes 2,4 and 7, they were only decreasing significantly in aggregate class 5. Indicators were increasing in aggregate class 8. Between 1990 and 1998 (Table 13.12) mesotrophic indicators in streamside plots are decreasing significantly in aggregate classes 2 and 6.

Table 13.9 Change in the number of plots that have at least one English Nature indicator for unimproved mesotrophic grassland between 1978 and 1990 over all plot types. A ?[2] test using unmatched plots was used to test for differences in the distribution of indicator species between the survey dates.

Aggregate class	*All plot types 1978*	*All plot types 1990*	*ChiSqr*	*Sig*	*Dir*
1	10	14	0.38	ns	+
2	36	29	0.55	ns	-
3	38	47	0.75	ns	+
4	81	23	31.24	***	-
5	29	15	3.84	ns	-
6	19	5	7.04	**	-
7	22	4	11.12	***	-
8	15	16	0.00	ns	+

Table 13.10; Change in the number of plots that have at least one English Nature indicator for unimproved mesotrophic grassland between 1978 and 1990 in streamside plots.

Aggregate class	*Streamside 78*	*Streamside 90*	*ChiSqr*	*Sig*	*Dir*
1					
2	9	7	0.06	ns	-
3	2	2	0.25	ns	NoCh
4	11	3	3.50	ns	-
5	6	0	4.17	*	-
6	3	3	0.17	ns	NoCh
7	4	0	2.25	ns	-
8	0	1	0.00	ns	+

Table 13.11 Change in the number of plots that have at least one English Nature indicator for unimproved mesotrophic grassland between 1990 and 1998 over all plot types.

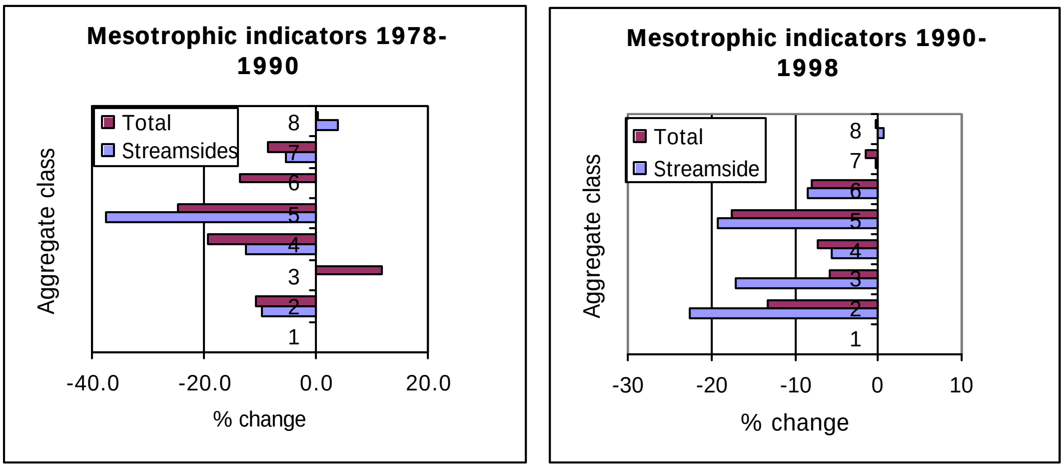
Aggregate class	All plot types 1990	All plot types 1998	ChiSqr	Sig	Dir
1	23	18	0.39	ns	-
2	241	169	12.30	***	-
3	194	170	1.45	ns	-
4	310	202	22.36	***	-
5	133	80	12.69	***	-
6	73	36	11.89	***	-
7	47	31	2.88	ns	-
8	29	28	0.00	ns	-

Table 13.12 Change in the number of plots that have at least one English Nature indicator for unimproved mesotrophic grassland between 1990 and 1998 in streamside plots.

Aggregate class	*Streamsides 1990*	*Streamsides 1998*	*ChiSqr*	*Sig*	*Dir*
1					
2	71	37	10.08	**	-
3	29	18	2.13	ns	-
4	42	25	3.82	ns	-
5	29	17	2.63	ns	-
6	21	6	7.26	**	-
7	6	5	0.00	ns	-
8	5	6	0.00	ns	+

32. Figures 13.6 a.) and 13.6 b.) demonstrate the changes in the percentage of plots containing one or more mesotrophic indicator. Mesotrophic indicators are decreasing in more aggregate classes in all plot types between 1990 and 1998 than between 1978 and 1990 and are also decreasing in streamside plots. Between 1978 and 1990 it was only in aggregate class 5 that mesotrophic indicators were being lost in streamsides at a greater rate than other plot types, however this has changed and between 1990 and 1998 they are decreasing at a greater rate in streamside plots than in other plot types in aggregate classes 2, 3, 5 and 6, indicating that if streamside plots were formerly refugia for these species in these habitats, they are now under threat. They are decreasing less rapidly than other plot types in aggregate classes 4 and 7 and continuing to increase in aggregate class 8.

Figure 13.6 a) The % change in the proportion of streamside plots containing at least one Mesotrophic indicator species between 1978 and 1990 compared to the % change in all plot types and b) The % change in the proportion of streamside plots containing at least one Mesotrophic indicator species between 1990 and 1998 compared to the % change in all plot types (N.B. there were no streamside plots in aggregate class I).



33. In summary, between 1990 and 1998 there has been a continuation of the trend detected for 1978-1990 for mesotrophic indicator species to decrease across the countryside in all plot types. Between 1978 and1990 the only habitat where streamside plots were losing indicator species at a greater rate than other plot types

was lowland woods, in other habitats such as infertile grassland, tall grass and herb and moorland grass mosaics species were being lost in streamsides but not at as great a rate as elsewhere in the countryside so streamsides may have been acting as a refugia. This has changed between 1990 and 1998, in tall grass and herb, fertile grassland, lowland woodland and upland woodland habitats indicators are being lost at a greater rate in streamsides than other plot types. Only in infertile grassland and moorland grass mosaics are streamsides possibly still acting as a refugia for indicator species. Mesotrophic indicators are increasing in streamside plots in upland heath and bog habitats which may be due to increasing pH and eutrophication.

Acidic indicators

34. In 1990, acidic grassland indicator species (taken from a list provided by English Nature) were recorded from a significantly greater proportion of streamside plots than any other plot type (Bunce *et al.*1999). In 1998 acidic indicator species were only associated more with streamsides in aggregate class 4 (Tables 13.13 and 13.14).

Table 13.13 Analysis of occurrence of unimproved mesotrophic grassland indicator species in 1998 by plot type and Aggregate class using 1990-1998 replicates. The counts are the total number of species occurrences.

Aggregate Class	*1998*	*B*	*H*	*RV*	*SW*	*X*	*Y*
1	30	4		1		22	3
2	444	105	40	103	130	18	48
3	545	90	2	196	85	112	60
4	4296	494	67	712	1158	880	985
5	199	36	49	7	31	41	35
6	2079	140	19	178	655	570	517
7	10711	564		707	4397	2543	2500
8	8869	152		87	2043	4336	2251

Table 13.14 The percentage of plots in 1998 containing at least one acidic indicator species. (the % is calculated by dividing the number of plots containing an indicator by the number of plots in that category in 1998).

Aggregate Class	*B*	*H*	*RV*	*SW*	*X*	*Y*
1	11.8	0.0	2.4	0.0	5.2	12.0
2	17.4	23.7	13.8	20.9	24.5	12.8
3	34.2	50.0	23.1	40.8	23.9	23.1
4	76.7	78.0	72.1	82.2	80.9	71.7
5	11.2	14.6	21.4	17.1	34.3	14.8
6	86.0	64.3	85.1	70.4	86.9	77.4
7	100.0	0	99.0	99.7	100.0	98.8
8	100.0	0	100.0	100.0	99.5	98.6

35. Over all plot types acidic indicator species were found to be decreasing more between 1990 and 1998 (Table 13.17) than between 1978 and 1990 (Table 13.15). Indicator

species were only decreasing in aggregate class 4 and even found to be increasing in aggregate class 3 between 1978 and 1990, whereas between 1990 and 1998 decreases were significant in aggregate classes 2 and 6 in addition to 4. In streamside plots indicator species were decreasing in aggregate class 4 between 1978 and 1990 (Table 13.16) and in 2,4 and 6 between 1990 and 1998 (Table 13.18). In upland moorland grass mosaics and heath/bog habitats acidic indicators were not changing significantly and were not decreasing in streamside plots.

Table 13.15 Change in the number of plots that have at least one English Nature indicator for unimproved acid grassland between 1978 and 1990 over all plot types. A $?^2$ test using unmatched plots was used to test for differences in the distribution of indicator species between the survey dates.

Aggregate class	*All plot types 1978*	*All plot types 1990*	*ChiSqr*	*Sig*	*Dir*
1	11	13	0.04	ns	+
2	35	40	0.21	ns	+
3	37	59	4.59	*	+
4	62	20	20.50	***	-
5	26	16	1.93	ns	-
6	17	7	3.38	ns	-
7	4	0	2.25	ns	-
8	5	0	3.20	ns	-

Table 13.16 Change in the number of plots that have at least one English Nature indicator for unimproved acid grassland between 1978 and 1990 in streamside plots.

Aggregate class	*Streamside 1978*	*Streamside 1990*	*ChiSqr*	*Sig*	*Dir*
1	0	0			NoCh
2	7	10	0.24	ns	+
3	2	2	0.25	ns	NoCh
4	14	2	7.56	**	-
5	6	5	0.00	ns	-
6	5	5	0.10	ns	NoCh
7	0	0			NoCh
8	0	0			NoCh

Table 13.17 Change in the number of plots over all plot types that have at least one English Nature indicator for unimproved Acid grassland between 1990 and 1998.

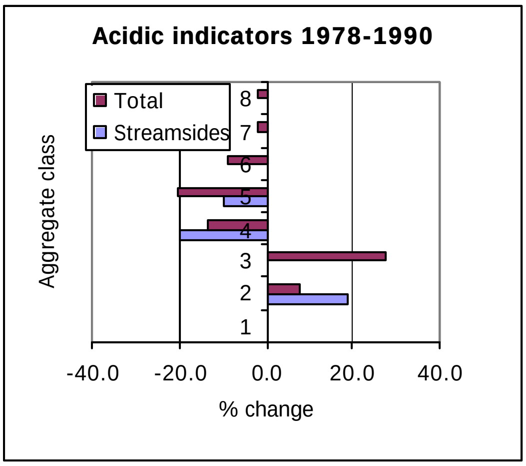
Aggregate class	*All plot types 1990*	*All plot types 1998*	*ChiSqr*	*Sig*	*Dir*
1	26	22	0.19	ns	-
2	321	143	67.52	***	-
3	200	167	2.79	ns	-
4	284	135	52.28	***	-
5	122	60	20.45	***	-
6	84	39	15.74	***	-
7	5	0	1.50	ns	-
8	4	1	2.25	ns	-

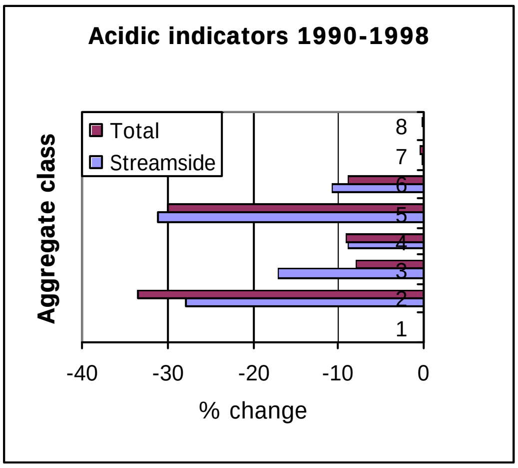
Table 13.18 Change in the number of streamside plots that have at least one English Nature indicator for unimproved Acid grassland between 1990 and 1998.

Aggregate class	*Streamside 1990*	*Streamside 1998*	*ChiSqr*	*Sig*	*Dir*
1	0	0			
2	73	36	36.92	***	-
3	25	15	1.17	ns	-
4	45	17	21.02	***	-
5	20	10	0.11	ns	-
6	34	17	32.03	***	-
7	1	0	0.00	ns	-
8	0	0			

36. Figures 13.7 a.) and 13.7 b.) demonstrate the changes in the percentage of plots containing one or more indicator of acid grassland. The patterns are quite different between 1978-1990 and 1990-1998. Indicator species were only decreasing at a greater rate than other plot types in aggregate class 4 between 1978 and 1990, they were even increasing in aggregate class 2. However, between 1990 and 1998 indicators are decreasing across all plot types in most aggregate classes. Aggregate classes 7 and 8 are not changing significantly. Similarly to the mesotrophic species between 1990 and 1998 they are being lost at a greater rate in streamside plots compared to other plot types in aggregate classes 3, 5 and 6. Acidic indicators are also decreasing in streamside plots in aggregate classes 2 and 4 but not as rapidly as in other plot types and are not changing in aggregate classes 7 and 8 (upland habitats).

Figure 13.7 a) The % change in the proportion of streamside plots containing at least one Acidic indicator species between 1978 and 1990 compared to the % change in all plot types and 13.7 b.) The % change in the proportion of streamside plots containing at least one Acidic indicator species between 1990 and 1998 compared to the % change in all plot types.





37. In summary there has been a decrease in acidic indicator species in all plot types across the countryside between 1990 and 1998. In some habitats; fertile grassland, lowland woods and upland woods, they are being lost more from streamside plots than other plot types. In tall grass and herbs and infertile grassland they are not decreasing as much as in other plot types. Indicator species were only found to be in greater proportions in infertile grassland than other plot types, it is possible that

streamsides are acting as a refugia for acidic indicators. In the upland habitats moorland grass mosaic and heath/bog acidic indicators are not changing significantly which is desirable. Although the patterns from mesotrophic indicators suggested that there may be some eutrophication this is not affecting the distribution of acidic indicators.

Wetland species

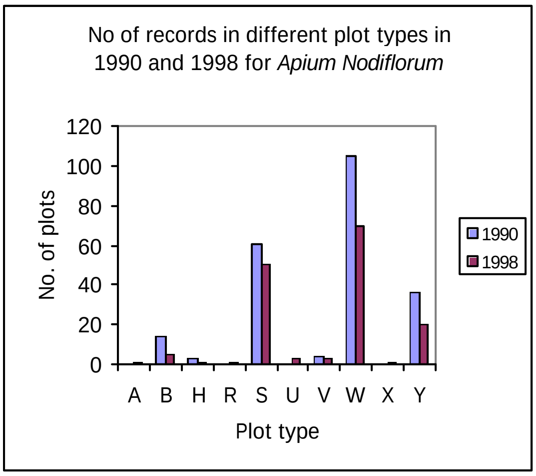
38. Streamsides provide a particularly moist environment and in some areas (e.g. open arable land) may provide the only habitat available for plant species and their associated fauna requiring such conditions. In order to investigate further the importance of streamside habitats to wetland species, 15 of the 73 species which were decreasing in at least one aggregate class and are uncommon and/or confined to wet habitats were selected (Table 13.19). Yellow pimpernel (*Lysimachia nemorum*) was included despite being a relatively common woodland species as it was one of the species referred to in the CS2000 report for which streamsides were thought to have become a refuge by the time of the 1990 survey.

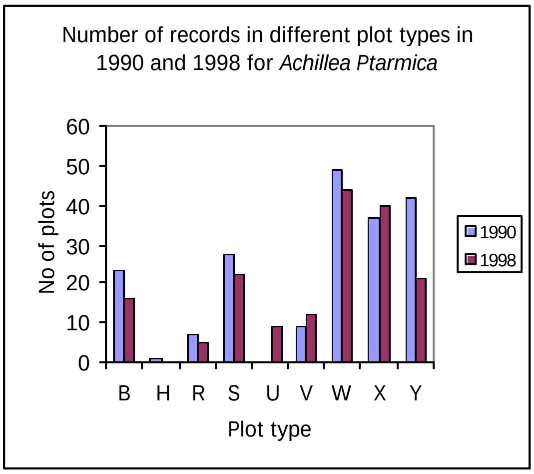
Table 13.19. Selected species for evaluation of importance of streamside habitats

Species	***Abundance and habitat preference***
Stellaria uliginosa (bog stitchwort)	Locally common streamsides, ditches, wet tracks, often on acid soils
Sparganium erectum (branched bur reed)	Locally common by ponds, lakes, slow rivers, canals, marshy fields and ditches
Persicaria hydropiper (water pepper)	Locally common in damp places and shallow water
Myosoton aquaticum (water chickweed)	Fairly common in EW, marshes ditches and banks of water courses
Myosotis scorpiodes (water forget-me-not)	Locally common by or in edges of ponds, rivers and in damp fields
Montia Fontana (blinks)	Locally common in damp areas
Lysimachea nemorum (yellow pimpernel)	Relatively common in woodlands
Lycopus europeaus (gypsywort)	Common in EW, fens, wet fields, lakes & rivers
Galium palustre (marsh bedstraw)	Common, pondsides, ditches, damp meadows and fens
Eriophorum vaginatum (hare's tail cotton grass)	Common in parts of Britain, wet peaty places especially moorland bogs
Drosera longifolium (great sundew)	Confined largely to Scotland in wet acid peaty places.
Conium maculatum (hemlock)	Common most of GB, damp ground, roadsides, ditches, waste ground
Carex echinata (star sedge)	Common in West and North, scattered elsewhere, bogs and marshes
Apium nodiflorum (fool's water cress)	Common to S Scot, local elsewhere, ditches, marshes, lakes and rivers
Achillea ptarmica (sneezewort)	Frequent damp marshy places

39. In order to investigate the importance of streamside habitats to these species their occurrence in different plot types in both the 1990 and 1998 surveys was looked at in detail. The proportion of occurrences in different plot types was calculated and plotted for each species for both 1990 and 1998. An example plot of the data is given for both *Apium nodiflorum* (Fools water cress) and Achillea ptarmica (Sneezewort). It is clear that streamside (S/W) plots are particularly important for Apium nodiflorum, whereas Achillea ptarmica is found in a wider variety of plots.

Fig 13.8. Number of records for *Apium nodiflorum* and *Achillea Ptarmica* in different plot types in 1990 and 1998.





40. The number of occurrences of each species in streamside plots as compared to their occurrences in all other plot types provides a measure of the importance of streamside habitats to that particular species. Table 13.20 shows the proportion of species records in streamside plots in both 1990 and 1998, the percentage decline in total records for each species between 1990 and 1998 and the percentage decline in streamside plots alone.

Table 13.20. The occurrence and changes in occurrence of selected species in streamside plots (S/W) 1990-1998.

Species	*% of all records that were in S/W plots 1990*	*% of all records that were in S/W plots 1998*	*% change ('90-'98) in no's of records in S/W plots*	*% change ('90-'98) in no's of records in all plots*
Stel uli	60	49	-13	3
Sparg ere	58	52	-61	-55
Pers hyd	61	61	-55	-55
Myo aqua	68	83	-74	-79
Myo scorp	73	68	-26	-20
Mon Font	56	34	-46	-11
Lysi nem	54	59	-29	-35
Lyco euro	77	65	-35	-23
Gal pal	56	50	-7	-19
Erio vag	20	10	-28	40
Dros long	31	0	-100	-94
Con mac	26	19	-45	-24
Car ech	45	37	-3	17
Api nod	74	77	-28	-21
Ach ptar	39	39	-13	-13

41. Is it possible to assess from these results whether the changes observed in streamside plots are having a detrimental affect upon species for which streamsides are a refugia? It is clear that for some of the species selected (e.g. *Achillea ptarmica*, see Fig 13.8) streamsides are not providing a refuge, as the species is recorded in a variety of plot types. The majority of species for which >50% of records were in streamside plots showed losses in streamsides plots that were greater or of a similar magnitude to losses across all plot types, suggesting that reductions in species richness in streamside plots included the loss of species for which streamsides are an important habitat.

Integration of freshwater data with vegetation data for adjacent plots

42. Measurements of the biological quality of watercourses were made in both 1990 and 1998 at RHS sites. An index system called the *Biological Monitoring Working Party* (BMWP) score[3] and the *River Invertebrate Prediction and Classification System* RIVPACS software[4] was used. The BMWP score system converts samples of aquatic macro-invertebrates into a set of simple numerical values. BMWP is the number of animals found weighted by a score relating to their pollution tolerance, high scores = good biological condition. Number of taxa (taxon richness) refers to the numbers of

species groups present. Average Score Per Taxon (ASPT) is a measure of the average pollution tolerance of the animals present. The RIVPACS system was developed to predict the taxon richness and ASPT to be expected at different sorts of site, if the sites were unpolluted. Biological condition of sites can be judged by comparing observed taxon richness and ASPT with what would be expected if the site was unpolluted. The value of the ratio observed/expected for each of these scores (EQI-BMWP, EQI-Number of taxa, EQI-ASPT) indicates the biological condition of the stream, with ratios approaching unity equating with unpolluted sites.

43. For this question, for the first time, the data collected under module 2 (Furse *et al.* 2002) and data from the terrestrial CS surveys have been combined in order to investigate the changes in streamside plots. As RHS sites were not associated with particular S/W plots it was necessary to screen the data in order to ensure that only plots actually located adjacent to RHS sites were used in the analyses. A number of RHS plots did not have associated S/W plots, whilst the majority had either one or two plots alongside the stretch of water surveyed (a small number had 4 or 5 plots associated with the RHS area).

44. The results of the 1990 and 1998 surveys showed that there were marked improvements in the biological conditions of the CS streams over the period 1990 - 1998. In order to test whether this improvement in biological water quality was a direct result of the changes in vegetation condition of streamside plots associated with watercourses (i.e. if the vegetation was acting as a buffer) regression analyses were carried out to test for relationships between vegetation condition (fertility, competitor, light and moisture scores and species richness) and biological condition of the watercourse (BMWP and RIVPACS scores). A summary table for these regressions is given in Table 13.21.

45. For many of the significant relationships in Table 13.21 the statistic explaining the variance in the data accounted for by the relationship between the two variables, was very low. Thus, although there is a definite relationship present between many of the condition measures for the streamside plots and both the biological and habitat quality of the watercourse with which they are associated, the latter measures do not explain the condition measures. In fact, for only four of the significant relationships in Table 13.21 is the amount of variance in the data explained by the relationship greater than 20%, with the vast majority being between 1 and 5%. This may be best illustrated by looking at plots of the data (Figs 13.9 and 13.10). The relationship between the fertility score and the observed ASPT is negative (Fig 13.9), highly significant and accounts for over 20% of the variance in the data. The relationship between species richness and the observed ASPT is positive and also highly significant, however it accounts for only 6% of the variance in the data.

Fig 13.9 Regression of fertility score in streamside plots in 1990 (N90) against the average pollution tolerance of the animals (OB_ASPT) in the adjacent watercourse,

$y = 6.88 - 0.40x$, $r^2 = 0.20$, $n = 258$, $p < 0.001$.

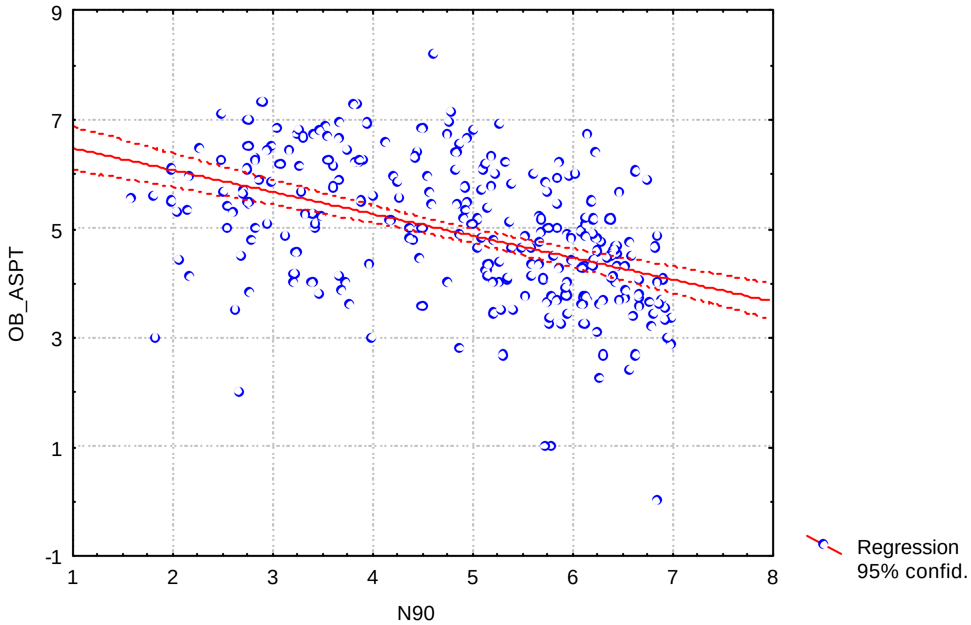


Fig 13.10. Regression of species richness in streamside plots in 1990 (SPRICH90) against the average pollution tolerance of the animals (OB_ASPT) in the adjacent watercourse, $y = 4.13 + 0.043x$, $r^2 = 0.06$, $n = 259$, $p < 0.001$.

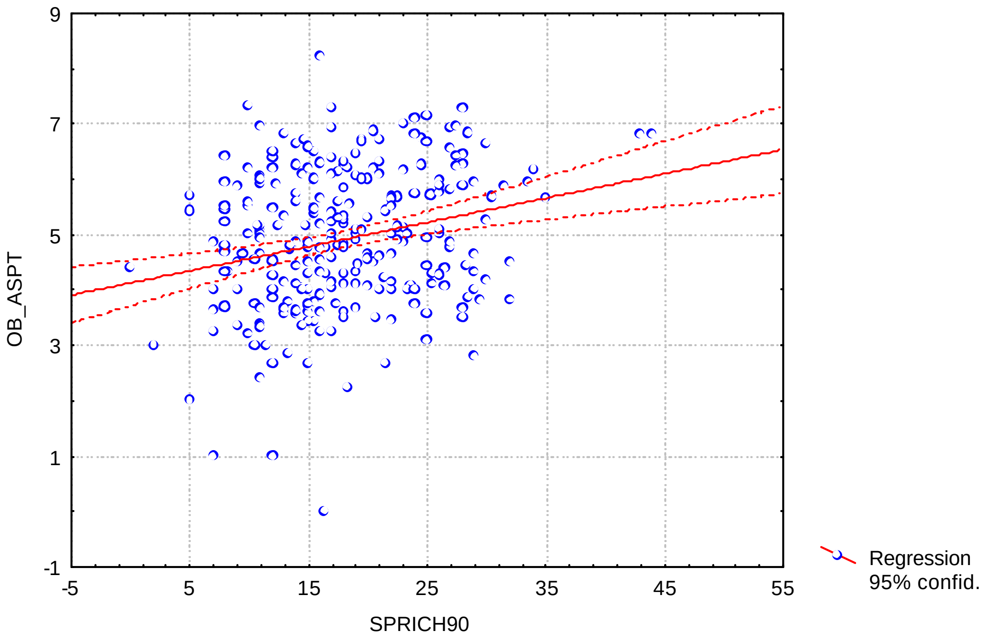


Table 13.21. Results of regression analyses on the relationships between vegetation condition measures (fertility, competitor, light and moisture scores and species richness) and BMWP and RIVPACS scores for adjacent watercourses. Results from regressions of BMWP and RIVPACS scores on light and moisture scores in 1990 are not shown as all were insignificant. The F ratios are given under each of the independent variables, significance levels are indicated as follows; *, P<0.05, **, P<0.01, ***, P<0.001, n.s., non-significant). +/- indicates the direction of the response, where + both dependent and independent variable are increasing, where – an increase in the dependent variable results in a decrease in the independent variable.

			F- ratio				Independent variables							
Dependent variable	df	total df	BMWP	+/-	No. of Taxa	+/-	ASPT	+/-	EQI-BMWP	+/-	EQI-No.of Taxa	+/-	EQI-ASPT	+/-
Sp richness ‘90	1	259	12.3***	+	6.2*	+	16.6***	+	7.1**	+	6.2*	+	8.8**	+
Competitor score ‘90	1	258	0.5 n.s.		3.7 n.s.		54.0***	-	0.2 n.s.		0.6 n.s.		20.5***	-
Fertility score ’90	1	258	0.1 n.s.		9.29**	+	67.5***	-	0.03 n.s.		1.4 n.s.		18.2***	-
Sp richness ‘98	1	294	17.3***	+	10.1***	+	24.5***	+	11.3***	+	10.1***	+	12.4***	+
Competitor score ‘98	1	294	2.3 n.s.		2.3 n.s.	+	77.0***	-	4.1*	-	1.4 n.s.		20.0***	
Fertility score ‘98	1	294	3.2 n.s.		3.0 n.s.		104.2***	-	5.7*	-	1.9 n.s.		26.8***	-
Moisture score ‘98	1	294	0.03 n.s.		3.2 n.s.		11.4***	+	0.2 n.s.		0.0 n.s.		2.5 n.s.	
Light score ‘98	1	294	13.4***	-	12.12***	-	4.4***	-	5.6*	-	3.5 n.s.		7.8**	-

What do these results tell us about changes in streamside plots?

Species Richness

46. Species richness in both '90 and '98 was always positively related to BMWP/RIVPACS scores, i.e. good biological condition of the watercourse was related to high values of species richness. Closer analysis of the data revealed that these relationships resulted, in part, from strong positive relationships in Environmental Zones 2 and 4 in both '90 and '98. It is therefore not unexpected that the decreases in species richness in streamside plots between '90 and '98 were related to decreases in the biological condition of the watercourses with which they were associated.

Ellenberg scores

47. Number of taxa in the watercourse was positively related to the fertility score of vegetation in the streamside plot in '90. The more fertile the vegetation, the higher the number of species groups in the watercourse. In both '90 and '98 the fertility score of the vegetation in the streamside plot was negatively related to; the average pollution tolerance of the animals present (ASPT), the observed/expected (EQI) BMWP (the number of animals found, weighted by a score relating to their pollution tolerance) and the EQI ASPT. These results show that the more fertile the vegetation, the higher the pollution tolerance of the taxa in the watercourse which is an indicator of poor biological condition of the stream. Closer analysis of the data showed that this was particularly the case in Environmental Zones 2 and 4. The competitor score of the vegetation in the streamside plot was also negatively associated with the average pollution tolerance of the animals present (ASPT) in both '90 and '98, as well as BMWP score, ASPT, EQI_BMWP and EQI_ASPT. These results were similar to those for fertility, showing that high competitor scores for the vegetation in the streamside plot were related to high pollution tolerance of the taxa in the watercourse again indicating poor biological condition of the stream. Finally, the light score of the vegetation in streamside plots in '98 was also negatively related to BMWP score, no. of taxa, ASPT, EQI_BMWP and EQI_ASPT. The greater the proportion of light loving species in the streamside plots, the lower the biological condition of the watercourse.

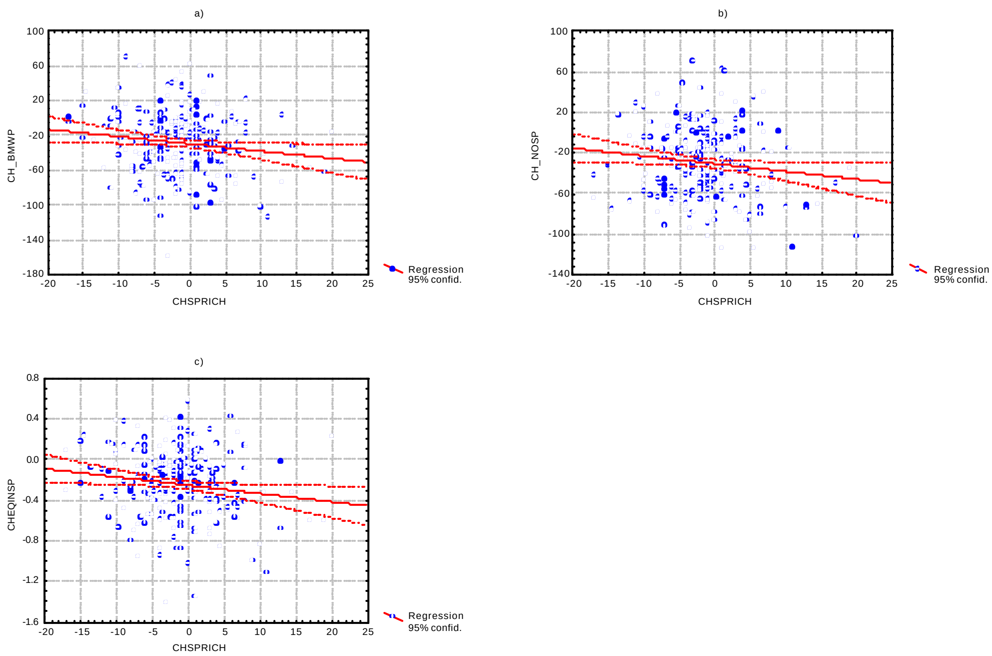
Change in vegetation condition v change in biological water quality

48. As data for BMWP and RIVPACS scores was collected in both 1990 and 1998, it was possible to look at change in the BWMP scores between 1990 and 1998 against changes in Ellenberg scores and species richness. These analyses showed that there were no significant relationships between the changes in Ellenberg moisture, competitor, fertility or light scores for streamside plots and changes in the BMWP and RIVPACS scores for adjacent watercourses. However, there were significant relationships between the decreases in species richness and increases in some of the BMWP and RIVPACS scores, summarised in Table 13.22 and Fig 13.11. This may have resulted from increasing rankness of vegetation providing shadier conditions for a larger range of stream invertebrates.

Table 13.22 Results of regression analyses on the relationships between change in species richness '90-'98 and change in BMWP and RIVPACS scores for the same period. Table 13.22 includes only variables with which there was a significant regression, analysis was carried out on change in all independent variables included in Table 13.21.

			Independent variables *F* ratio		
Dependent variable	df	total df	Change BMWP	Change no. of taxa	Change EQI no. of taxa
Change in species richness	1	242	4.8*	4.2*	5.1*

Fig 13.11. Regressions between change in species richness 1990-1998 (CHSPRICH) and a) change in BMWP (CH_BMWP), b)change in number of taxa (CH_NOSP) and c) change in the ratio of observed/expected number of taxa (CHEQINSP). In all cases $r^2 = 0.01$.



Impacts of land management adjacent to the watercourses

River Habitats Survey Data

49. The River Habitats Survey (RHS) was carried out for the first time as part of Countryside Survey in 2000. It is a standard assessment procedure for evaluating the physical structure of a watercourse based on a standard 500m survey section, taking account of both in-stream and bankside features. The two scores derived from the information collected as part of the RHS are the HQA (habitat quality assessment) and the HMS (habitat modification score). The results of CS2000 showed HQA values to be highest in Scotland and

lowest in the easterly lowlands of England, showing that the structural diversity of river corridors in Scotland was high, whereas that of the easterly lowlands was low. Conversely the HMS, which measures the extent of channel modification by people, was highest in the easterly lowlands of England and lowest in Scotland (Haines-Young *et al*. 2000). In all environmental zones with the exception of the uplands BMWP scores and HQA/HMS scores showed significant correlations, with the biological condition of streams highly correlated with habitat quality.

50. It has been noted that the poorest vegetation condition measures recorded by CS2000 may coincide with the best River Habitats Survey (RHS) scores. In order to test whether there was any statistical basis for this notion, analyses were carried out to test for significant relationships between vegetation condition (fertility, competitor, light and moisture scores and species richness) for streamside plots and data collected on the RHS scores for the river/stream with which the plot was associated. The relationships were explored using regression analysis, a summary table of the significant regressions are given in Table 13.23. (N.B. Data for HQA and HMS scores was collected for the first time in 1998, hence regressions against these variables are only carried out with the 1998 data, and it is not possible to look at change).

51. The regressions carried out between the selected Ellenberg scores (light, moisture, fertility, competitor) and species richness and the habitats quality assessment (HQA) and modification score (HMS) from the RHS in 1998 were almost all significant . However, as with the regressions on the BMWP and RIVPACS scores, the variance in the data accounted for by the regressions was generally low, with more than 20% of the variance in the data explained by the regression in only two cases (competitor score v HMS and fertility score v HMS).

Table 13.23. Results of regression analyses on the relationships between vegetation condition measures (fertility, competitor, light and moisture scores and species richness) and RHS scores (HQA and HMS).

			Independent variables			
			F ratio			
Dependent variable	df	total df	HQA	+/-	HMS	+/-
Sp richness '98	1	299	7.4**	+	14.7***	-
Competitor score '98	1	299	23.3***	-	88.4***	+
Fertility score '98	1	299	13.4***	-	107.3***	+
Moisture score '98	1	299	6.8**	+	47.7***	-
Light score '98	1	299	54.1***	-	0.4 n.s.	

What do these results tell us about changes in streamside plots?

52. In general the results show that the idea that the poor vegetation condition measures recorded by CS2000 may coincide with the best River Habitats

Survey (RHS) and BMWP/RIVPACS scores does not hold for species richness scores, although it does for a number of the Ellenberg scores.

Species richness

53. Species richness was positively related to HQA, i.e. the better the habitat quality, the higher the species richness. Conversely, species richness was negatively related to HMS, i.e. the more modified the habitat, the lower the species richness.

Ellenberg scores

54. HQA was negatively related to fertility, competitor and light scores in ’98, indicating that high fertility, light levels and an increase in competitive species were related to low habitat quality. HQA was positively related to the occurrence of plant species dependent on soil moisture. Conversely, HMS was negatively related to the moisture score of species in the streamside plot. The more modified the watercourse the lower the numbers of moisture loving species. HMS was positively related to competitor and fertility scores. Modified habitats tended to contain species typical of competitive, nutrient rich vegetation.

Impact of adjacent Broad Habitat

55. As part of Module 2 of Countryside Survey (Furse *et al.* 2002), buffer zones of 20m width were created on either side of the RHS survey area, using the CS spatial database, in order to try to assess the impacts of adjacent Broad Habitats on the condition of both the stream and the associated habitats. The results showed strong significant relationships between the Broad Habitat of the riparian zone and indices of river corridor condition. In particular, there were negative correlations between the *Arable and Horticultural* Broad Habitat and both habitat and stream condition and positive correlations between the woodland Broad Habitats and habitat and stream conditions. Habitat modification scores were positively correlated with the extent of *Arable and Horticultural*, *Improved Grassland* and *Built-up and Gardens* Broad Habitats and negatively correlated with *Acid Grassland, Bog, Woodland, Fen, Marsh and Swamp* and *Dwarf Shrub Heath* (Furse *et al.* 2002).

56. As these buffers had already been created, it was decided that they would also be used to measure the impact of adjacent Broad Habitat on vegetation condition scores for the S/W plots for this question. Plots within each square were assigned to the Broad Habitat which constituted the highest percentage of land within the spatial buffer zone, resulting in a number of plots for each Broad Habitat. In order to investigate whether different Broad Habitats impacted differently on condition scores, analysis of variance (ANOVA) was carried out between Broad Habitats to see how Ellenberg scores and species richness varied. There were significant differences in terms of both species richness and Ellenberg scores between Broad Habitats.

Species richness

57. S/W plots associated with riparian areas containing a higher proportion of *Improved Grassland* than any other Broad Habitat had significantly lower species richness than plots associated with predominantly *Bog, Dwarf Shrub Heath* or *Fen, Marsh and Swamp* Habitats ($F_{13, 283} = 2.9$, $p<0.001$) (the one plot which was predominantly supra-littoral rock had a particularly high species richness and was excluded from the analysis).

Ellenberg scores

58. Significant differences between Broad Habitats for Ellenberg scores (fertility score, $F_{13, 283} = 6.3$, $p<0.001$, moisture score, $F_{13, 283} = 2.4$, $p<0.01$, light score, $F_{13, 283} = 2.7$, $p<0.01$, competitor score, $F_{13, 283} = 4.7$, $p<0.001$) were largely due to differences between mean scores for the Bog Broad Habitat and all other Broad Habitats. The *Bog* Broad Habitat had lower fertility than *Broadleaf Woodland*, *Arable and Horticultural*, *Improved* and *Neutral Grassland*, and high light and moisture scores relative to all the above with the exception of *Neutral grassland* (for moisture and light) and *Arable and Horticultural* (for light). Competitor scores were also low for plots associated with *Bog* in comparison with those associated with *Broadleaf Woodland*, *Arable and Horticultural* and *Improved Grassland*.

Change in species richness and Ellenberg scores

59. Changes in species richness and Ellenberg scores for plots associated with different Broad Habitats were looked at in the same way. However, apart from a significant difference between Broad Habitats in relation to a change in species richness ($F_{13, 259} = 1.82$, $p< 0.05$), which is due to increases in species richness in *Dwarf Shrub Heath* as compared to losses in *Coniferous Woodland*, *Improved Grassland*, *Arable and Horticultural* and *Bog* Broad Habitats, there were no significant results.

60. These results suggest that while the Broad Habitat of the riverine area has an effect upon both species richness and Ellenberg scores, it is not very easy to pick up signals of change by looking at the Broad Habitat level. The increases in species richness in *Dwarf Shrub Heath* relative to other Broad Habitats picked up by the analysis of change, agrees with results on aggregate classes shown in Fig.13.2. The increase in species richness in such habitats is more a sign of eutrophication than of increasing habitat quality.

Impact of fences

61. In order to investigate whether the changes in the vegetation associated with streamside plots was the result of fencing off of streamsides a 5m buffer was put around each plot within GIS to investigate whether or not a fence was present in 1990 or 1998 and whether there was any change in fences in that period. Only 58/1825 plots had a fence within 5m of the SW plot. Of these, 11 plots showed gains in fences between 1990 and 1998 and 5 showed losses. It was concluded that these numbers were far too low to have resulted in the changes in vegetation scores recorded for S/W plots.

62. (A 10m buffer was also used but due to the proximity of S/W plots to each

other and resulting overlaps in buffer zones in a number of cases it became very difficult to assess relationships between particular plots and any adjacent fences. It was also clear that whilst fences may be picked up within GIS at a distance of 10m it would not follow that they were being used to fence off the streamside. It was considered that fencing of a streamside would be unlikely to involve fences being placed at a distance much greater than 5m from the bankside).

Watercourse management

63. This question investigates the vegetation associated with watercourses as surveyed in CS2000. It has also been possible to look at the RHS and water quality (biological) data for the associated watercourse. Whilst these aspects of the waterside environment give some indication of habitat quality, they tend to concentrate on vegetation and stream invertebrates. However streamside habitats are also important for other species groups and their changes are likely to impinge on those species. As well as providing shelter streamside vegetation also regulates the light and temperature regime of the river (Naiman et al. 1993). Examples of such species and their habitat requirements are outlined below.

64. Water voles are given priority status for conservation under the UK BAP and have been added to the list of species protected under the Wildlife and Countryside Act 1981. Water voles prefer watercourses with a slow current and avoid polluted water (McLaren 1998). Banks need to have a structurally diverse vegetation with shoots and leaves at a range of height levels and the vegetation needs to be continuously distributed. A range of vegetation types is suitable including wetland, grassland and ruderal plant communities, however, dense woodland or scrub beside the watercourse is consistently avoided. Species favourable to water voles may include willowherb (*Epilobium* sp.), purple loosestrife (*Lysimachia vulgaris*), and meadow sweet *(Filipendula ulmaria*) fringed by thick stands of rushes, sedges or reeds (Environment Agency 2000). Habitat patches need to be at least 500m long, the isolation of habitat patches and populations can cause local extinctions.

65. For many species associated with watercourses, as for water voles, requirements include good water quality, lack of disturbance and bankside vegetation, e.g. otters, wildfowl and many invertebrate species. However, as for water voles, the requirements of individual species may be very specific; the southern damsel fly and the glutinous snail require regular ditch clearing and grazing to maintain an open habitat structure, the hairy click beetle is found on reed canary grass and is threatened by overgrazing or scrub encroachment, river shingle beetles are threatened by habitat loss, increases of invasive plant species and land use changes, the tansy beetle is under threat from loss of its host plant, the tansy, due to shading out by Himalayan balsam (*Impatiens glandulifera*) and Willow (*Salix* spp.), passerine birds benefit from persistent stands of reeds and tall emergents and myxomycete species require moist conditions and decaying water margin vegetation.

66. It is not clear to what extent CS data can inform us about how the changes in streamside plots between 1990-1998 are likely to have impacted upon

individual species and time constraints have limited the amount of work in this area done here. Work by others in these areas may provide ideas for potential uses of the data. For example, habitat monitoring of the WFA option of the Habitat scheme by ADAS analysed the vegetation to discover whether it was suitable for water voles (McLaren 1998). This was done by calculating suited species scores for grazing and poaching. A low grazing score and a low poaching score is good because it reflects reduced grazing and lack of disturbance. Canopy height was examined indirectly by classifying species according to their potential canopy height and determining the range and variation of canopy height amongst bankside species. Although suited species scores are not part of the CS methodology, it would be possible to look at canopy height of bankside species. However, the extent of useful information this would provide in terms of changes in available habitat for water voles is questionable.

67. CS was never designed to provide information at such a level and whilst it has been possible to pick up general trends within streamside plots and to look in more detail at effects on plants and streamside invertebrates, it is unwise to attempt to predict impacts on other species in anything other than a very general way. Overall, the improvement in water quality observed in Countryside Survey is beneficial to all species using the river, streams and streamside habitats. However, the impacts of the changes in vegetation observed in CS are more difficult to determine. An increase in rankness of streamside vegetation may be good for water voles as they prefer tall structurally diverse vegetation, however, increases in shrubby species such as *Crategus monogyna* or *Rubus fruticosus* close to the water side would not be favourable. Taller rank vegetation may also be favourable for some invertebrate species, however, where invertebrate species are associated with a specific plant an increase in rankness where competitive species proliferate may shade out the host species which will have a detrimental effect. Bird abundance and diversity may increase in more shrubby, wooded riparian strips (Deschênes et al. 2003) and can be correlated with habitat diversity, however, management for maximum diversity can be detrimental to rare bird species (Stauffer 1980). Overgrown streamsides may prevent them acting as a refugia for smaller herbaceous plant species but may provide a buffer that soaks up nutrients providing a beneficial effect on water quality. Streamsides are complex habitats on which a whole range of species groups depend.

68. The optimum management of such habitats requires a balance to be found between the functions which streamsides perform, both as habitats for a range of species and in terms of how they affect adjacent watercourses. As an interface between terrestrial and aquatic systems they are relatively complex with variable flood regimes, diversity of soil and vegetation types and increased dispersal of propagules including introduction of alien exotic species. It appears that current management of streamsides is far from comprehensive. Contact with bodies having policy involvement with the management of watercourses revealed that whilst the water in the watercourses and its management are clearly the responsibility of one body (i.e. the EA) the management and, by implication the health of the adjacent habitats, are largely the responsibility of the land owner whose land they pass through. It is recognised that habitats adjacent to watercourses are important

for a range of species (plants, mammals, birds, invertebrates, and other lesser known groups such as the myxomycetes) including a number of BAP species, but influence over their management is largely a matter of the provision of advice. The exception being the EA which may act to protect these habitats when approached by land managers in regard to regulation or operational activities (e.g. discharge or flood defence) concerning the watercourse. Whilst EN provides advice on sustainable flood defences aimed at enhancing river edge habitats, much of the advice provided by other bodies (EA, DEFRA, FWAG), such as the encouragement towards the creation of buffer strips, is aimed at promoting the biological quality of the water, rather than waterside habitats per se. There are many questions that need answering about the use of buffer strips to promote water quality (Osborne and Kovacic 1993) such as; what size should a buffer strip be? What type of vegetation is required? does saturation by nutrients take place reducing efficency? and, does species composition make a difference? The individual characteristics of each watercourse and the impacts of buffer strips on other species will need to be taken into consideration, it could be misleading to make a buffer strip policy too generalised.

69. The current piecemeal management of watercourses may well be a factor in changes recorded in streamside vegetation between 1990 and 1998. The fact that advice on management of land adjacent to watercourses comes from various bodies, some with conflicting aims, and few with any power to actually alter the way in which the land is managed may have resulted in the general trends observed. If the Water Framework Directive is able to achieve strategic catchment level management of watercourses taking into account both water quality and the quality of the waterside habitats themselves for both the flora and fauna which inhabit them, it will vastly improve upon the current situation.

SUMMARY STATEMENT

- Whilst the CS data provides convincing evidence that there have been changes in streamside plots between 1990 and 1998, it does not in itself provide sufficient information to detect the causes for those changes.
- Good quality water is related to good quality vegetation adjacent to it, indicating that the gains in water quality have been independent of changes in waterside vegetation. This casts some doubt on the possibility that buffer strips are the reason for declining vegetation quality, although they may have been created, but failed to achieve their aims.
- The data also reveals that the changes in vegetation are of concern .In most cases species which rely on streamsides are being lost there, as they are in the wider countryside. This will undoubtedly impact upon species which utilise those species, either specifically or for the habitat which they provide.
- The WFD is likely to significantly impact on the future management of streamside habitats. This study indicates that a comprehensive strategy looking at all aspects of watercourses and their associated habitats is necessary to ensure that the management of streamsides balances all the various landscape functions which they perform.

Further work and recommended changes to CS methodology

- During the 1998 survey, the River Habitats Survey and CS survey were carried out by different survey teams. If better information is to be gathered on possibly conflicting management in the riparian zone, the assessments may need to be carried out in parallel or by one team. The area surveyed by the River Habitat Survey should contain at least one CS plot.
- The surveyors should ensure that the stream number (from the physiography mapping sheet) is written on the plot sheet so that it is clear which stream is associated with which plot.
- More detailed information about the watercourse would make it possible to investigate how changes relate to particular watercourse types, e.g. width, depth, direction of flow, etc.
- This question has highlighted the potential importance of management information as supplementary data. The question about whether the changes in streamside vegetation are as a result of increases in buffer strips being left or planted alongside watercourses could potentially be answered if management information revealed that landowners had been following advice and creating buffer strips. Such information would eliminate a lot of speculation and guess work.
- In order to understand more fully relationships with other species, there should be attempts to relate vegetation data to survey data for birds and mammals, as they become available.
- The observed relationships between habitat quality and streamside vegetation will require time series data if they are to be understood more fully. A repeat River Habitats Survey should therefore again be conducted alongside the next Countryside Survey.
- Moreover, future analyses of water quality/vegetation relationships should target catchment level processes, taking into account land cover and estimated nitrogen fluxes across entire catchments.

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Appendix 1

Table 13.24 shows the significant results for unweighted Ellenberg values by EZ.

Variable	Env. Zone	N	Mean 1990	Mean 1998	SD 1990	SD 1998	Diff	Dir.	Sig.
Fertility score (N)	1	394	6.28	6.37	0.65	0.66	0.08	+	***
Fertility score (N)	4	236	5.05	5.13	1.17	1.14	0.08	+	**
Fertility score (N)	5	268	3.39	3.45	1.10	1.07	0.06	+	**
Fertility score (N)	6	257	3.01	3.08	0.83	0.80	0.06	+	*
Light score (L)	2	443	6.45	6.31	0.66	0.75	-0.14	-	*
Light score (L)	3	223	6.58	6.56	0.57	0.58	-0.03	-	***
Light score (L)	4	236	6.71	6.67	0.42	0.46	-0.04	-	***
Light score (L)	5	268	7.00	6.99	0.42	0.45	-0.01	-	***
Light score (L)	6	257	6.90	6.93	0.34	0.36	0.03	+	***
Moisture score (F)	1	394	6.10	6.05	0.56	0.55	-0.05	-	***
Moisture score (F)	3	223	6.50	6.45	0.54	0.52	-0.06	-	***
Moisture score (F)	4	236	6.32	6.30	0.58	0.61	-0.02	-	***
Moisture score (F)	5	268	6.70	6.65	0.65	0.65	-0.05	-	***
Moisture score (F)	6	257	6.63	6.64	0.54	0.52	0.01	+	***
pH score (R)	1	394	6.51	6.58	0.49	0.47	0.06	+	***
pH score (R)	4	236	5.59	5.64	0.82	0.81	0.05	+	*
pH score (R)	5	268	4.44	4.50	0.87	0.90	0.06	+	*
pH score (R)	6	257	3.95	4.02	0.76	0.74	0.07	+	*

Table 13.25 shows the significant results for unweighted Ellenberg values by Agg. class

Variable	Agg. class	N	Mean 1990	Mean 1998	SD 1990	SD 1998	Diff.	Dir.	Sig.
Fertility score (N)	3	118	5.86	5.97	0.39	0.56	0.11	+	**
Fertility score (N)	4	352	5.08	5.19	0.65	0.76	0.11	+	***
Fertility score (N)	5	129	6.19	6.13	0.48	0.53	-0.06	-	*
Fertility score (N)	6	202	4.81	4.88	0.89	0.93	0.07	+	*
Fertility score (N)	7	389	3.22	3.27	0.50	0.53	0.05	+	**
Fertility score (N)	8	171	2.08	2.15	0.37	0.44	0.08	+	**
Light score (L)	3	118	7.05	6.97	0.33	0.29	-0.08	-	***
Light score (L)	4	352	6.82	6.79	0.23	0.28	-0.03	-	***
Light score (L)	5	129	5.58	5.44	0.46	0.61	-0.14	-	***
Light score (L)	6	202	6.02	5.92	0.48	0.57	-0.10	-	***
Light score (L)	7	389	6.89	6.88	0.23	0.29	-0.01	-	***
Light score (L)	8	171	7.30	7.30	0.29	0.29	0.01	+	***
Moisture score (F)	2	459	6.12	6.02	0.56	0.55	-0.10	-	***
Moisture score (F)	4	352	6.32	6.33	0.51	0.51	0.01	+	***
Moisture score (F)	5	129	5.87	5.83	0.31	0.32	-0.04	-	***
Moisture score (F)	6	202	6.29	6.26	0.42	0.48	-0.04	-	***
Moisture score (F)	7	389	6.64	6.59	0.41	0.44	-0.05	-	***
Moisture score (F)	8	171	7.28	7.23	0.60	0.57	-0.05	-	***
pH score (R)	2	459	6.57	6.60	0.30	0.36	0.03	+	**
pH score (R)	4	352	5.72	5.77	0.43	0.52	0.06	+	**
pH score (R)	7	389	4.18	4.23	0.57	0.58	0.05	+	*
pH score (R)	8	171	3.22	3.30	0.49	0.59	0.08	+	*

Table 13.26 shows the significant results for cover-weighted Ellenberg values by Aggregate class within Environmental zone.

Variable	Env. zone	Agg. class	N	Mean 1990	Mean 1998	St dev 1990	St dev 1990	Diff.	Dir.	Sig.
Fertility score (N)	4	4	97	5.15	5.24	0.62	0.66	0.09	+	*
Fertility score (N)	4	6	35	5.07	5.23	0.83	0.81	0.16	+	**
Light score (L)	3	5	7	5.11	4.96	0.37	0.25	-0.16	-	*
Light score (L)	3	6	44	5.90	5.91	0.42	0.50	0.01	+	***
Light score (L)	3	7	88	6.80	6.78	0.21	0.23	-0.02	-	***
Light score (L)	3	8	26	7.24	7.15	0.37	0.34	-0.08	-	***
Light score (L)	4	2	46	6.63	6.59	0.23	0.23	-0.04	-	***
Light score (L)	4	3	18	6.92	6.91	0.11	0.15	-0.01	-	***
Light score (L)	4	4	97	6.83	6.79	0.21	0.24	-0.03	-	***
Light score (L)	4	6	35	6.06	5.93	0.46	0.46	-0.13	-	**
Light score (L)	4	7	27	6.96	6.92	0.21	0.31	-0.05	-	***
Light score (L)	4	8	11	7.37	7.42	0.19	0.26	0.05	+	***
Light score (L)	5	2	3	6.80	6.91	0.20	0.20	0.11	+	*
Light score (L)	5	3	8	7.03	7.03	0.10	0.09	0.01	+	**
Light score (L)	5	4	46	6.94	6.97	0.25	0.28	0.03	+	***
Light score (L)	5	6	23	6.24	6.27	0.57	0.43	0.03	+	***
Light score (L)	5	7	122	6.97	6.94	0.23	0.36	-0.03	-	***
Light score (L)	5	8	65	7.39	7.38	0.27	0.28	0.00	-	***
Light score (L)	6	4	26	6.79	6.83	0.21	0.21	0.05	+	***
Light score (L)	6	6	18	6.22	6.24	0.31	0.34	0.02	+	***
Light score (L)	6	7	147	6.86	6.89	0.22	0.24	0.03	+	***
Moisture score (F)	3	6	44	6.22	6.24	0.35	0.41	0.02	+	***
Moisture score (F)	3	7	88	6.62	6.56	0.38	0.45	-0.06	-	***
Moisture score (F)	3	8	26	7.18	6.94	0.70	0.72	-0.25	-	***
Moisture score (F)	4	2	46	5.97	5.89	0.38	0.35	-0.08	-	***
Moisture score (F)	4	4	97	6.31	6.28	0.48	0.51	-0.02	-	***
Moisture score (F)	4	6	35	6.19	6.13	0.43	0.44	-0.06	-	***
Moisture score (F)	4	7	27	6.97	6.90	0.36	0.50	-0.07	-	***
Moisture score (F)	4	8	11	7.56	7.61	0.35	0.47	0.05	+	**
Moisture score (F)	5	4	46	6.17	6.25	0.39	0.49	0.08	+	***
Moisture score (F)	5	6	23	6.23	6.29	0.40	0.33	0.07	+	***
Moisture score (F)	5	7	122	6.65	6.57	0.44	0.46	-0.08	-	***
Moisture score (F)	5	8	65	7.47	7.37	0.52	0.53	-0.09	-	***
Moisture score (F)	6	4	26	6.23	6.26	0.48	0.40	0.02	+	***
Moisture score (F)	6	6	18	6.10	6.17	0.46	0.41	0.07	+	***
Moisture score (F)	6	7	147	6.58	6.55	0.39	0.39	-0.03	-	***
pH score (R)	5	8	65	3.42	3.55	0.42	0.52	0.13	+	*