ENGLISH
NATURE

The long-term effects of cutting on the yield, floristic composition and soil nutrient status of chalk grassland

No. 71 - English Nature Research Reports

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English Nature Research Report

Number 71
The long-term effects of cutting on the yield, floristic composition and soil nutrient status of chalk grassland

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Final report (Contract HF3-08-26)

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Further copies of this report are available from the nominated officer at English Nature, Northminster House, Peterborough, PE1 1UA

ISSN 0967-876X

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EXECUTIVE SUMMARY

1. This report describes the results of an experiment aimed at investigating the long-term effects of cutting on the yield, floristic composition and soil nutrient status of chalk grassland. The experiment was carried out at Knocking Hoe, National Nature Reserve, Bedfordshire for a period of 23 years (1965 to 1988).

2. Three cutting treatments(cut once in May; cut twice, in May and June; and cut thrice, in May, June and July) were applied annually in a randomised block experiment replicated four times. Using a split-plot design, cut material was either removed from half of the sub-plots or was returned as finely ground material.

3. The effects of the various treatments on floristic composition were estimated by detailed dry weight analysis of plots in 1971 and 1987. Effects on selected soil properties (pH, organic matter content, extractable K, Ca, Mg, Mn and total N and P) were estimated by detailed sampling of soils in 1973 and 1987.

4. The total annual above ground yield of plots cut once a year was greater than for plots cut twice or thrice a year in 17 out of 24 years.Mean annual yield(dry weight) for plots cut once, twice and three times a year was 194, 176, and 151 g m2 respectively. Plots to which cuttings were returned consistently out-yielded plots from which cut material was removed, although significant differences ($p < 0.05$) were only recorded in 14 out of the 24 years.

5. Seven years after the experiment began, control plots(not cut) had significantly fewer species than plots which were cut(19 compared to 30).By 1987, the control plots were dominated by scrub and coarse, tussocky Bromus erectus and the number of species present had fallen to 16.3.In contrast, cut plots contained between 27 to 37 species. There was no significant difference in the number of species in plots cut once, twice or three times a year in either 1971 or 1987.

6 Cutting had a significant effect ($p<0.05$) on 24 species in 1971 and on 35 species in 1987.Twenty-one species showed a significant difference in both years. Twelve out of 53 species present were not significantly affected by any treatment(mostly species of low frequency).Details of the response of individual species are presented in Tables 3.11 and 3.12.

7. After 7 years, only one species(Galium verum) showed a significant response to the return or removal of cut material. By 1987, 16 species showed a significant response. Nine species were more abundant in plots to which nutrients had been returned. These were: Bromus erectus, Carex flacca, Campanula glomerata, Campanula rotundifolia, Centaurea nigra, Leontodon hispidus, Pimpinella saxifraga, and Plantago lanceolata. Seven species were more abundant in plots from which nutrients had been removed. These were:
Festuca ovina, Asperula cynanchica, Linum catharticum, Lotus corniculatus, Onobrychis viciifolia, Scabiosa columbaria and Succisa pratensis.

8. The proportion of K,Mg and N in the vegetation was significantly different between cutting treatments and all elements except for K were

significantly different in the vegetation from the different cutting dates. Nitrogen was the only element to show a significant trend with time with a 17% increase in mean value over 20 years.

9. There were no significant differences between treatments in the total amount of nutrients removed annually in the cut vegetation. The amount (g m-2 year-1)of K,Ca, Mg, P and N removed annually was calculated as 1.84, 1.66, 0.26,0.17 and 2.66 respectively.

10. There was no significant difference in pH, organic matter content and extractable K in soil from any treatment in 1973, although there were significant differences in % N,% P,Mn and Mg.
In 1987, there were significant differences in the soils beneath the various treatments(Tables 3.22, 3.23 and 3.24).
Plots to which cut material was returned had significantly higher values for K than remove plots, whereas plots from which vegetation was removed had higher levels of Na,Mg and Mn. There were no significant differences in the amounts of P or N, nor in pH or organic matter content.

11. Cutting had a significant effect on the flowering and reproductive capacity of species. Most species flowered more profusely in cut plots, compared with uncut controls, although 3 species(*Carex flacca, Filipendula vulgaris* and *Poterium sanguisorba*)had significantly more inflorescences in control plots.

12. The relevance of the results of this experiment to the management of chalk grassland for nature conservation are discussed and evaluated.

1 INTRODUCTION

Chalk grassland is a biotic plagioclimax which has been maintained in the past by grazing animals, principally sheep, cattle and rabbits. Prior to the advent of myxomatosis in 1953-54 few studies had been made of the effects of different management treatments on chalk grassland, probably because grazing by sheep and rabbits was observed to maintain a short, open generally species-rich turf which supported a characteristic fauna. It is now widely accepted that if the biological interest and richness of chalk grasslands is to be maintained, some form of management, employing grazing animals or a substitute for grazing such as mowing, must be used.

Grazing has always been, and is likely to remain, the preferred management option, partly because it is the traditional method of land management which has been responsible for creating and maintaining the biological interest and partly because it creates a more diverse range of micro-habitats than other forms of management. Nevertheless, there is often a diversity of views on what is the best form of management for a particular site or area. Morris (1971) has quite rightly argued that it essential to define objectives of management clearly and has presented evidence in numerous publications to support this view with particular reference to invertebrate animals (see Morris 1978 for a review).

The influence of systems of management upon the botanical composition of downland have received scant attention, except for studies by Norman (1957), Kydd (1957), Wells (1969) and Hawes (1971). The use of sheep for managing chalk grasslands for the purposes of nature conservation was pioneered by the

Nature Conservancy at Aston Rowant but even on large nature reserves, maintaining grazing animals outside a farming system has not been without its problems. Where reserves are small, which is often the case with sites owned or managed by Wildlife Trusts, using grazing animals is attended by many problems and alternative methods are needed. The most obvious alternative is some form of cutting or mowing.

A replicated, small scale experiment to investigate the effects of cutting on the botanical composition of chalk grassland was laid down on a steep, south-facing slope on the Barton Hills, Bedfordshire in 1963. This experiment compared the effects of time of year of cutting and frequency of cutting with sheep grazing. The results were presented in Wells (1971 and 1980).

Experience gained from this experiment was used to design a larger experiment, which included measuring the effect of removing or returning cut plant material on the botanical composition of the sward. This experiment, at Knocking Hoe National Nature Reserve, Bedfordshire, began in 1965, with the first stage being completed in 1975. The results from the first 11 years were made in a report to the Nature Conservancy Council (Wells 1976). In the following years (1976 to 1986), experimental treatments were maintained and dry weight measurements continued, but except for occasional notes, no detailed measurements were made of the floristic composition of the plots.

In August 1987, NERC were commissioned by the Nature Conservancy Council to undertake a programme of research into the effects of cutting on chalk grassland. The objectives, as stated in the contract were:

"To assess and publish the results of 21 years completed work of cutting and removing cuttings on:

(1) the botanical composition of chalk grassland and

(2) the nutrient status of chalk grassland"

To provide detailed information for this contract, detailed soil and vegetation measurements were made on all plots at Knocking Hoe in 1987. This report provides an analysis of these data and combined with information gathered previously provides an assessment of the long-term effects of cutting on the floristic composition of chalk grassland.

2 METHODS

2.1 SITE DETAILS

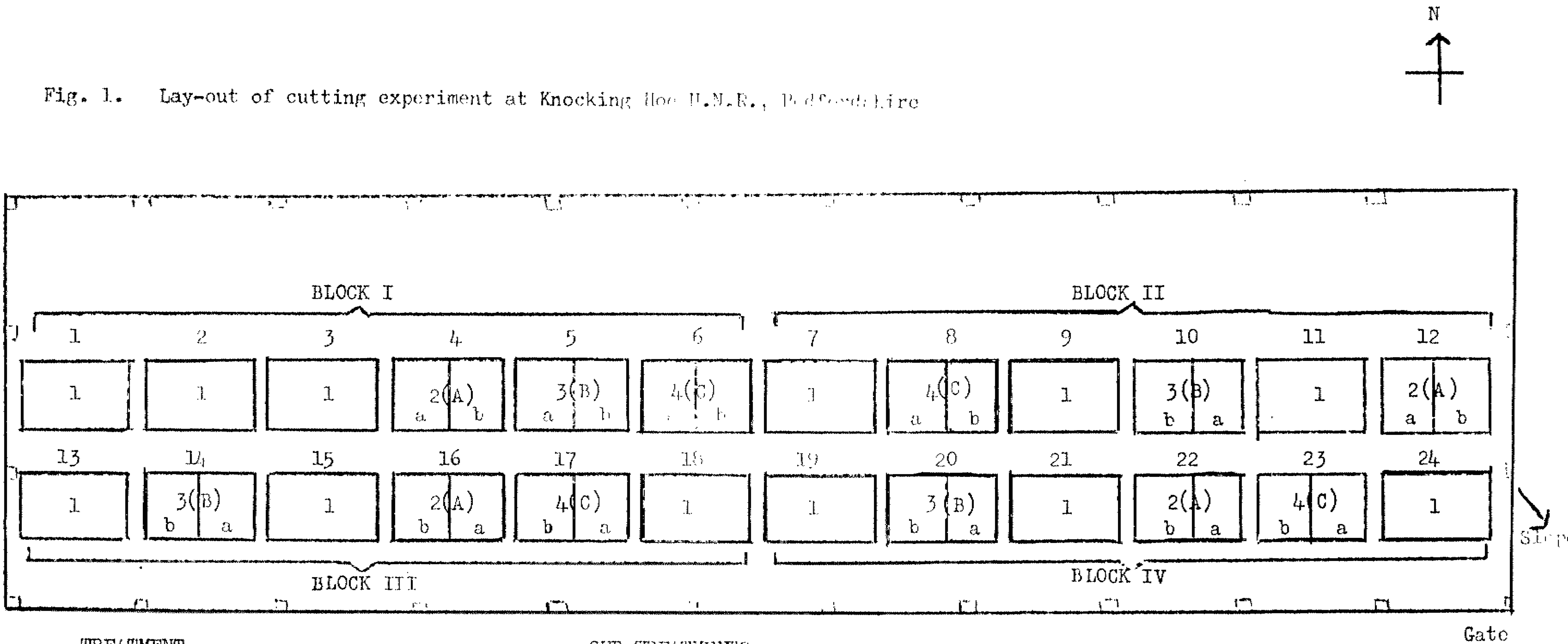
The study area is situated on a steep, south-facing slope within the Knocking Hoe National Nature Reserve in Bedfordshire (Grid reference TL 131308). The site was selected for its apparent uniformity in vegetation structure and absence of scrub. There is no evidence that the site has ever been ploughed. The grassland, which is a typical Mesobrometum, (CG3 in the NVC) had been grazed for the past 70 years or more by a combination of sheep, cattle and rabbits, but precise details of stock numbers are lacking.

The soils on the slope are highly calcareous and are mainly derived from the Lower Chalk, with small additions of brown earth material originating from glacial drift which occupies the hill tops.

2.2 EXPERIMENTAL DETAILS

A sheep and rabbit-proof exclosure, 33 x 12 m was erected in July 1964 on the most convex part of the slope, with the long axis of the exclosure along the contour of the slope. Within the exclosure, 24 plots, each 2.44 x 1.52 m were laid down in 4 blocks, with guard rows of 30 cm between each plot (Fig. 1). Three cutting treatments and three untreated plots (control plots) were allocated at random to each block. The purpose of having 3 control plots in each replicate was to enable control plots to be harvested at intervals when the composition of all plots was to be determined by harvesting and sorting into species. This was done in 1971 (7 years uninterrupted succession to

Fig. 1. Lay-out of cutting experiment at Knocking Hoe N.N.R., Bedfordshire



TREATMENT

1	Control - not cut
2(A)	Cut in May
3(B)	Cut in June and May
4(C)	Cut in July, June and May

SUB-TREATMENTS

a = Cut material removed

b = Cut material returned

Main plot size 8' x 5'

Sub-plot size 4' x 5'

1' Guard row between plots

3' between Blocks I, II, and III, IV.

scrub) and again in 1987 (23 years of uninterrupted succession to scrub), leaving one control plot per replicate for a final harvest at the end of the experiment.

The three cutting treatments were (1) cut once a year in May; (2) cut twice a year in May and June; and (3) cut thrice a year in May, June and July. In addition, the cut plots were split into two subplots; one half chosen randomly had the clippings returned as fine ground plant material and the other half had its clippings removed. Plots were cut with hand shears as close to the ground as possible (< 1 cm), the cut material being removed from the plots, dried for 48 hrs at 85°C in a forced-draught oven and weighed to constant weight. Plant material which was to be returned to the plots was ground in a rotary mill to a fine powder and scattered evenly over the sub-plot by hand, 2-3 days after cutting. Sub-samples of the ground plant material were taken for chemical analysis from material which was not returned to the plots.

2.3 ESTIMATION OF BOTANICAL COMPOSITION

To enable meaningful comparisons to be made with records of botanical composition made previously, the same methods used in 1971 were employed in 1987.

All plots which had been cut annually since 1965 were cut to ground level on 1 June 1987. In addition, 4 plots (numbers 2, 11, 15 and 21) which have not received any treatment since being enclosed in 1964, and 4 plots (numbers 1, 9, 13 and 19) which had last been cut in 1971, were cut to ground level. The cut material was stored at -20°C and subsequently sorted into individual species and dead plant material.

Dry weights were determined after drying for 48 hrs at 85°C. The dry weight data provide the most accurate estimate of the long-term effects of the various cutting treatments on the floristic composition of the grassland. They also provide the raw data for looking at changes which occur in the plots which were not managed in any way for 23 and 16 years respectively.

2.4 FLOWER COUNTS

The effect on flower production of annual cutting compared with not managing chalk grassland was estimated by counting inflorescences of 18 and 23 species in May and August 1988 respectively.

Inflorescences of *Bromus erectus* were counted and weighed in May 1987 and 1988 in an attempt to see if cutting frequency, and the return or non-return of nutrients affected the reproductive performance of this dominant grass.

2.5 SOIL CHEMICAL ANALYSIS

In March 1987, soil samples were collected from each of the 48 sub-plots of the experiment (6 from sub-plots receiving the annual cutting treatment, with and without the return of nutrients, 2 from sub-plots last cut in 1971, 4 from plots which had received no treatment since 1964 x 4 blocks). Before samples were taken, litter, mosses and any other vegetation was removed. At each randomly determined sampling point, two 2.5 cm diameter cores 5 cm deep were collected, pooled, air-dried and sieved to pass a 2 mm mesh. Five samples were taken from each sub-plot, 240 samples (5 x 48) being taken in all for analysis.

The following measurements were made by the Chemical Section, Merlewood Research Station using standard soil analytical procedures (Allen *et al.* 1974):

pH - determined electrometrically in air-dry soil diluted 1:2.5 with water, stood 30 minutes and stirred.

Loss-on-ignition (L.O.I.) - determined at 375°C over 16 hours using the method of Ball (1964).

Total nitrogen - determined colorimetrically by auto-analyser, following digestion of soil with H_2SO_4, K_2SO_4 and H_gO.

Exchangeable K, Mg, Mn and Na were extracted in neutral N ammonium acetate, using 6 g soil to 200 ml extractant, shaken for 1 hour. K and Na were measured by flame photometry, Mg and Mn by atomic absorbtion spectrophotometry.

'Extractable' P was extracted in 0.5 m sodium bicarbonate, using 5 g soil to 100 ml extractant (shaken for 30 minutes), and determined colorimetrically after acidification.

The same sampling strategy and methods of chemical analysis were used on soils sampled from the same plots in February 1973. This enables direct comparisons to be made of changes in soil chemical properties over a 14 year period in plots subjected to carefully documented management practices.

2.6 CHEMICAL ANALYSIS OF VEGETATION

In order to calculate the quantities of some important chemical elements removed or returned annually in the cut vegetation, samples of the dried, finely ground vegetation were taken annually for analysis from 1965-87 (except for 1984, when the samples were lost). The amount of N, P, K, Ca, Mg and Fe in the samples was determined using standard analytical procedures (Allen *et al.*, 1974). The quantity of chemical element removed or returned annually to each sub-plot was calculated by multiplying the dry weight of the vegetation in each sub-plot by the amount of chemical element in the vegetation sample.

2.7 STATISTICAL ANALYSIS

After appropriate transformations, all data were subjected to ANOVA, using the standard SAS programme on the VAX computer at Monks Wood.

3 RESULTS

3.1 EFFECTS OF CUTTING ON ABOVE GROUND DRY MATTER YIELD

3.1.1 Effect of cutting on annual yield

The total annual yield of plots cut once a year was greater than for plots cut twice a year or three times a year in 17 out of the 24 years of this experiment. These differences were significant from 1969 to 1976 ($p<0.05$ or greater), but thereafter although the general trend remained the same, differences were only significant in 3 years out of 12 in the period 1977 to 1988 (Table 3.1).

Mean annual above ground dry matter yield for the 24 year period 1965-88 was 194.05 g m^2 for plots cut once a year, 176.51 g m^2 for plots cut twice a year and 151.84 g m^2 for plots cut three times a year. There was considerable between year variation: lowest yields were recorded in 1976 following the exceptionally dry winter of 1975 and the 'great drought' of 1976. Plots cut once, twice and thrice had yields of 141.8, 86.5 and 71.1 g m^2 respectively. In contrast, highest yields for plots cut once and twice a year occurred in 1972 (302.9 and 228.4 g m^2) when rainfall was well above average. Yields of greater than 200 g m^2 were recorded in 1965 (236.8 g m^2). 1967 (234.5 g m^2), 1985 (203.0 g m^2) and 1988 (201.2 g m^2) in plots cut three times a year. A common factor linking these years was higher than average winter and spring rainfall, coupled with mild winters.

In plots cut once a year, at the end of May, the above ground dry matter yield represents the growth of new plant material and accumulated dead material made in the 12 months since last cut. In plots cut twice a year, the yield of material at the first harvest represents 11 months growth; for plots cut three times a year, the first harvest represents 10 months growth since the last cut. With the exception of 1965 and 1987, the yield of above ground dry matter at the end of May in plots cut once a year was significantly greater ($p<0.05$ or greater) than in plots cut twice or three times a year (Table 3.2). The contribution made by the first harvest (in May) to the total annual yield of plots cut twice a year was 78.5%; for plots cut three times a year it was 68.1%.

The second harvest, taken at the end of June represents the regrowth made in one month since the first cut was taken. For the period 1965 to 1988, the mean dry matter yield at the second harvest was 37.94 g m^2 for plots cut twice a year, and 32.99 g m^2 for plots cut three times a year (not significant).

There was considerable between year variation in the above ground dry matter accumulated in the month of June (Table 3.3). Exceptionally low yields were recorded in 1973 and 1976 (5.8 and 7.75 g m^2 respectively), compared with 73.0 and 87.05 g m^2 recorded in 1967 and 1981.

The third harvest taken at the end of July is the regrowth made in the one month since the previous cut made at the end of June. The mean yield for the period 1965 to 1988 was 15.37 g m^2 which is less than half the mean yield made in the previous month. There was considerable between year variation in the dry matter produced in July, ranging from 3.65 g m^2 in 1975 to 35.75 g m^2 in 1973 (Table 3.4). These differences are probably associated with the ability of the plants to mobilise reserves to produce new leaf material in an environment which is changing from month to month with respect to water and nutrient supply.

3.1.2 Effect of returning cut material on above ground yield

In both total annual yield and first cut yield, plots where cuttings were returned as finely ground-up material produced a greater above ground dry weight than plots from which cuttings were removed (Tables 3.5 and 3.6). These differences became significant ($p<0.05$ or greater) in 1971 and this trend continued until 1988, although differences were not significant in 1987 and 1988. For the 24 years of this experiment, the mean annual yield of plots to which clippings were returned was 189.7 g m^2, compared with 158.5 g m^2 for plots which received no clippings ($p< 0.05$).

The return of clippings had no significant effect on yields at the June harvest each year until 1978, when plots receiving clippings yielded significantly more herbage ($<p<0.01$) than plots from which clippings were removed. This trend continued until 1988 (Table 3.7), although differences were not significant at the 5% level in 1980, 1986, 1987 and 1988.

Plots cut for a third time (in July) failed to show any significant differences between plots (Table 3.8). Nevertheless, plots to which cuttings were returned out-yielded those from which cuttings were removed since 1975.

The results of returning cut material may be summarised as follows:

Table 3.9 Number of significant results ($p<0.05$) between plots to which (a) clippings returned and (b) clippings removed, 1965 to 1988. Maximum of 24 possible.

	First cut (May)	Second cut (June)	Third cut (July)
Return greater than removal	14	7	0

3.1.3 **Interaction between cutting treatments and the return or non-return of clippings**

There was no evidence of any significant interaction between the frequency of cutting and the return of cuttings on plot yield.

3.2 EFFECTS OF CUTTING ON FLORISTIC COMPOSITION

Dry weight analyses made in 1971 and 1987 of individual plots were used to assess the effect of different cutting treatments on the floristic composition of plots subjected to the same treatments for 7 and 23 years respectively. Data for each species were analyzed separately using standard ANOVA procedures. A summary of the detailed ANOVA for individual species is presented in Table 3.10. Species which were significantly affected by the various cutting treatments are identified in Table 3.11; species which responded significantly to the return or removal of cut material are listed in Table 3.12.

3.2.1 **Number of species**

Of the 53 species recorded in the dry weight samples, 45 were recorded in both 1971 and 1987; four species (Festuca arundinacea, Gentianella amarella, Senecio integrifolius and Trifolium pratense) were only recorded in 1971 while four species (Centaurea scabiosa, Lolium perenne, Rhamnus catharticus and Sonchus oleraceus) were only found in 1987. All were present in only very small quantity and it is noteworthy that three of the species are annuals or short-lived perennials (Gentianella, Sonchus and Senecio) and are known to fluctuate greatly from year to year.

In 1971, seven years after the experiment began, control plots (not cut) had significantly ($p<0.05$) fewer species than plots which were cut (19, compared to 30.4), but there was no significant difference in the number of species in plots cut once, twice or three times a year (29.0, 30.6 and 29.4 respectively).

By 1987, 23 years after the experiment began, the number of species in the control plots had fallen to 15.3, whereas the number of species in cut plots remained much the same as it had been 16 years previously (27 to 37 species per plot, mean 29.6) (Table 3.13). Details of changes in the control plots are presented and discussed later in 3.3.

3.2.2 Species which were not significantly affected by any of the treatments

Twelve species (out of 53) showed no significant effect of any treatment in either 1971 or 1987. These species consisted of 3 grasses (Dactylis glomerata, Festuca arundinacea and Lolium perenne), 8 forbs (Carlina vulgaris, Gentianella amarella, Hypochaeris maculata, Picris hieracioides, Pulsatilla vulgaris, Senecio integrifolius, Senecio jacobaea and Trifolium pratense) and a seedling of Quercus robur. All were present in the plots at low frequencies or were present as isolated individuals in only one or two plots, and it is therefore not surprising that in the ANOVA they showed no significant trends.

3.2.3 **Species which showed a significant($p<0.05$ or greater) effect of cutting**

In the randomised block analysis, 24 species were significantly different in 1971 and 35 in 1987. Twenty-one species showed a significant difference in both years (Tables 3.10 and 3.11).

The following comments made regarding the performance and response of individual species to the 3 cutting treatments and to not being cut for 16 and 21 years respectively are based on the dry weight ANOVAs presented in Tables 3.10 and 3.11 and the detailed dry weights for individual species in all plots not presented here but stored at Monks Wood.

<u>Brachypodium sylvaticum</u>. Not present in any of the cut plots, but present in some quantity in plots cut 16 years ago. Surprisingly absent from plots which had not been cut for 23 years.

<u>Briza media</u>. Present in significantly greater quantities in plots cut twice or three times a year than in plots cut once a year. Absent from plots not cut for 16 or 23 years, although present in those plots when the experiment began.

<u>Bromus erectus</u>. In 1971, present in significantly greater quantity in plots cut once a year and in plots not cut for 7 years than in plots cut twice or three times a year. In 1987, still the dominant grass in

all plots but significantly more in plots not cut for 16 and 23 years than in plots receiving a cutting treatment. (105 and 100 g m^2 in control plots and 83, 62 and 46 g m^2 in plots cut once, twice and three times respectively.)

Festuca ovina. Present in significantly greater quantities in plots cut twice and three times a year than in plots cut once a year in 1971, with the same trend continuing in 1987. Only surviving as a 'trace' in plots not cut for 16 or 23 years.

Helictotrichon pratense. After 23 years, present in significantly greater quantities in plots cut three times a year than in plots cut twice or once a year. However, significantly more of this species in cut plots than in control (uncut) plots.

Koeleria gracilis = K. macrantha. Present in greatest quantity in 1971 in plots cut three times or twice a year. In 1987, significantly more of this species in plots cut twice and three times than plots cut once. All cut plots having significantly more than control plots.

Sieglingia decumbens. Not plentiful in any plot but significantly more of this species in cut plots than in control plots.

Carex caryophyllea. Significantly more of this species in the cut plots than in control plots in 1987, but differences between the cut plots not significant. Survives in the control plots as thin, etiolated shoots.

Carex flacca. Significantly more of this species in plots uncut for 7 years than in cut plots in 1971; this trend continued and in 1987 plots which had not been cut for 17 and 23 years contained significantly more of this species than plots cut once, twice or three times a year.

Asperula cynanchica. Significantly more of this species in 1971 in plots cut twice and three times a year than in plots cut once a year or in plots not cut for 7 years. By 1987, plots cut three times a year contained significantly more Asperula than plots cut twice or once a year. This species was lost from plots not cut for 23 years and was only present as a 'trace in plots not cut for 17 years.

Campanula glomerata. Significantly more of this species in plots cut twice or three times a year, but surprisingly persisting in small quantity in control plots.

Centaurea nigra. Present in good quantity in all treatments with significantly more of this species in plots which had not been cut for 17 years.

Centaurea scabiosa. Appears to be unable to withstand cutting and only present in quantity in plots not cut for 17 and 23 years.

Chrysanthemum leucanthemum = Leucanthemum vulgare. Only present in small amount in all plots, but significantly more in plots cut three times than in other plots.

Cirsium acaulon. Significantly more of this species in plots cut twice and three times a year, but nevertheless persisting in uncut plots.

Crataegus monogyna. The major shrub in the uncut controls, with dry weights of 839 g m^2 in plots not cut for 23 years and 133 g m^2 in plots not cut for 17 years. Absent from plots cut three times a year and only present as seedlings in plots cut once and twice a year. (0.07 and 0.004 g m^2 respectively)

Filipendula vulgaris. Significantly more of this species in the uncut plots than in plots receiving cutting treatments. In 1987, 7.57 g m^2 in plots not cut for 23 years, 8.75 g m2 in plots cut 17 years ago and only c. 0.5 g m^2 in plots cut annually.

Galium verum. Most plentiful in plots cut once a year or in plots not cut for 7 or 17 years. Does not benefit from frequent cutting.

Helianthemum chamaecistus. Significantly more of this species in plots not cut for 7 years in 1971, but although more plentiful in 1987 in plots not cut for 17 and 23 years, not significantly more abundant than in cut plots. A species which seems to do well in both regularly cut plots and in uncut vegetation.

Hieracium pilosella. Present in only small amounts in cut plots and absent in 1987 from all control plots. A species which requires short, regularly managed grassland in which to survive.

Hippocrepis comosa. Significantly more of this species in plots cut twice or three times than in plots cut once. Only very small quantities persist in the control plots.

Leontodon hispidus. Significantly more of this species in plots cut once or twice than in plots cut three times. Persists in small quantity in plots not cut for 17 and 23 years.

Linum catharticum. Significantly more of this species in cut plots than in control plots, with a tendency to be more prolific in plots cut once or twice than in plots cut three times a year.

Lotus corniculatus. A species which does equally well in both cut and uncut plots.

Pimpinella saxifraga. No significant differences between cutting treatments but significantly less Pimpinella in plots not cut for 23 years than in other plots.

Plantago lanceolata. No significant differences between any treatments.

Plantago media. Significantly more of this species in plots cut three times a year than in other cutting treatments. Absent from plots not cut for 17 and 23 years.

Polygala vulgaris. Significantly more of this species in cut plots than in uncut plots, with a trend for the plant to be most prolific in plots cut three times a year.

Poterium sanguisorba. Significantly more plentiful in plots not cut for 7, 17 and 23 years than in cut plots. Nevertheless, this species can survive quite well under a cutting regime, including cutting three times a year.

Primula veris. Significantly more of this species in the uncut plots than in cut plots.

Prunella vulgaris. In 1971, this species was more abundant in plots cut twice or three times a year but by 1987 there were no significant differences between treatments, although Prunella was absent from plots not cut for 23 years.

Ranunculus bulbosus. Significantly more plentiful in plots cut twice or three times a year than in plots cut once a year or not cut for 7, 17 or 23 years.

Rhamnus catharticus. A woody shrub only present in the uncut controls and most plentiful in plots not cut for 23 years.

Rosa canina. Present in considerable quantities in plots not cut for 23 years (137.4 g m^2) and in plots not cut for 17 years (5.0 g m^2); absent in 1987 from plots cut three times a year and present as a few small seedlings in other cutting treatments.

Scabiosa columbaria. Significantly more plentiful in cut plots than in uncut controls. Absent from plots not cut for 23 years.

Sonchus oleraceus. Present in small amounts in cut plots, absent from control plots.

Succisa pratensis. Significantly more abundant in cut plots than in control plots.

Thymus pulegioides. Significantly more plentiful in plots cut twice or three times a year than in plots cut once a year or not cut at all.

Viola hirta. In 1971, this species was significantly more plentiful in plots cut once a year than in plots cut twice or three times a year, or in plots which had remained uncut for 7 years. By 1987, this species was most plentiful in plots which had been uncut for 23 and 17 years and was least abundant in plots cut three times a year. This apparent reversal is probably explained by the fact that in 1971 subspecies calcarea was the most common Viola hirta present, whereas by 1987 this had been replaced by mostly subspecies hirta.

3.2.4 Species for which the return or removal of cut material(nutrients) had a significant effect.

In 1971, 7 years after the experiment began, only one species (Galium verum) had a significantly higher dry weight in plots to which nutrients had been returned as finely ground plant than plots from which plant material had been removed for 7 years.

By 1987, 23 years after the experiment began, 16 species showed a significant response to the return or removal of nutrients (Table 3.12). The following 9 species were more abundant in plots to which nutrients were returned than in those from which nutrients had been removed for 23 years: Bromus erectus, Carex caryophyllea, Carex flacca, Campanula glomerata, Campanula rotundifolia, Centaurea nigra, Leontodon hispidus, Pimpinella saxifraga, and Plantago lanceolata.

As groups, grasses, sedges and mosses had significantly higher dry weights in plots to which cut material was returned than plots from which it was removed, although it should be noted that for certain species, for example Festuca ovina, that was not the case.

Seven species were more abundant in plots from which nutrients had been removed for 23 years. These were: Festuca ovina, Asperula cynanchica, Linum catharticum, Lotus corniculatus, Onobrychis viciifolia, Scabiosa columbaria and Succisa pratensis. For the remaining 37 species the removal or return of plant material had no significant effect on their above ground dry matter.

3.2.5 Composition and structure in June 1987 of plots cut once a year for 23 years.(Table 3.14).

Vegetation 13 to 20 cm tall with inflorescences of Bromus erectus reaching 80 cm. Structurally, the vegetation consisted of a mixture of small tufts and tussocks of Bromus erectus, intermingled with a variety of other grasses and forbs. Mosses were abundant and there was a small amount of dead plant material (litter) present at the base of the grassland.