On average, Bromus erectus accounted for 79% of the above ground biomass, Helianthemum (3.0%), Carex flacca (2.5%), Poterium sanguisorba (1.9%), Festuca ovina (1.5%), Cirsium acaulon (1.2%) and Thymus pulegioides (1%) being the only other species to contribute 1% or more to the total above ground biomass. The above mentioned 7 species accounted for 91% of the above ground biomass, 15 other species (see Table 3.14)contributing to another 8%, with 24 species being present in very small amounts and contributing less than 1% to the total biomass. Nevertheless, 46 species were recorded from the 8 plots which were cut once a year, and it is clear that even though the contribution of individual species may be small under this cutting regime, species diversity is maintained.

The following species were noted in flower in at least some of the plots at the end of May, 1987: Briza media, Bromus erectus, Carex flacca, Festuca ovina, Filipendula vulgaris, Helianthemum chamaecistus, Hippocrepis comosa, Hieracium pilosella, Linum catharticum, Koeleria gracilis, Plantago lanceolata, Polygala vulgaris, Poterium sanguisorba, Primula veris and Ranunculus bulbosus.

3.2.6 Composition and structure in May 1987 of plots cut twice a year for 23 years (Table 3.15).

Vegetation 10 to 15 cm tall with inflorescences of Bromus reaching 50 to 75 cm. Structurally much more open than plots cut once a year, with patches of forb-rich grassland forming a mosaic with other grasses such as Festuca ovina and Koeleria gracilis.

Compared with plots cut once a year, much less Bromus and consequently greater contributions made by other grasses and forbs. Bromus accounted for 71% of the total above ground biomass. Substantial contributions were made by the following 10 species: Festuca ovina (4%), Cirsium acaulon (3.6%), Helianthemum chamaecistus (3%), Helictitrichon pratense (1.9%), Thymus pulegioides (1.8%), Asperula cynanchica (1.6%), Carex flacca (1.6%), Poterium sanguisorba (1.3%), Pimpinella saxifraga (1.1%) and Koeleria gracilis (1.1). With Bromus these 11 species accounted for 92% of the total above ground biomass. Twenty-nine other species contributed to the remaining 8% of above ground biomass, none contributing more than 1%. (see Table 3.15). In some plots, species such as Thymus formed large patches, whereas in others they were only present as occasional tufts.

Nationally rare or uncommon species such as Hypochoeris maculata and Pulsatilla vulgaris occurred in some plots and both survived and flowered under this management regime.

The following species were noted as flowering at the end of May 1987 in at least some plots: Asperula cynanchica, Briza media, Carex caryophyllea, Filipendula vulgaris, Helianthemum chamaecistus, Helictitrichon pratense, Hippocrepis comosa, Hypochoeris maculata, Koeleria cristata, Linum catharticum, Polygala vulgaris, Poterium sanguisorba, Primula veris and Ranunculus bulbosus.

3.2.7 Composition and structure in June 1987 of plots cut three times a year for 23 years(Table 3.16).

Short (2 to 6 cm), species rich turf, with scattered tufts of Bromus erectus in a matrix of Festuca ovina and a great variety of forbs.

Inflorescences of grasses were scarce, compared with their abundance in other treatments. Mosses not conspicuous. My notes for plot 17 record "structure similar to sheep-grazed downland". The most striking feature of the plots cut three times a year was the fine-grained texture of the turf and the intimate mosaic of grasses and forbs formed as a result of this cutting regime. Bromus erectus still accounted for the highest proportion of the above ground biomass (60.8%), but was present as isolated tillers and did not form the tufts or tussocks seen in the other treatments. The proportion of other species increased with the following species making substantial contributions: Cirsium acaulon (5.7%), Festuca ovina (5.6%), Helianthemum chamaecistus (3.6%), Carex flacca (3.2%), Helictotrichon pratense (3.1%), Asperula cynanchica (2.8%), Thymus pulegioides (1.9%), Poterium sanguisorba (1.6%), Centaurea nigra (1.4%), Koeleria gracilis (1.1), Pimpinella saxifraga (1.1%), Scabiosa columbaria (1%) and Carex caryophyllea (1%). These 14 species accounted for 94% of the total above ground biomass, 26 other species contributing to the remaining 6% of biomass (see Table 3.16).

The following species were recorded in flower: Asperula cynanchica, Briza media, Festuca ovina, Helianthemum chamaecistus, Hieracium pilosella, Hippocrepis comosa, Hypochoeris maculata, Koeleria gracilis, Leucanthemum vulgare, Linum catharticum, Plantago lanceolata, Polygala vulgaris, Poterium sanguisorba, Ranunculus bulbosus and Senecio integrifolius.

3.3 EFFECTS OF NO MANAGEMENT AFTER 7,16 AND 23 YEARS

Three "control" plots were included in each replicate of the experiment with the objective of providing a means of estimating the changes in structure and composition of plots which were not subject to a management treatment (cutting). One of these "control" plots from each replicate was harvested in 1971 to provide data on what had occurred during the 7 years which had elapsed since the experiment began. These same plots were allowed to regrow after being harvested in 1971, and provided, in 1987, an estimate of the effect of no management for a period of 16 years. One set of "control" plots, which had not been cut since the experiment was set-up, were harvested to provide an estimate of the effect of no management for a period of 23 years. The remaining set of "control" plots were left for harvesting at some time in the future.

3.3.1 **Composition of plots not cut for 7 years**

At the end of May 1971, the above ground vegetation of the control plots had the following composition:

dead plant material,mostly grasses	74.4%
live grasses, mostly Bromus erectus	18.8%
live sedges, mostly Carex flacca	0.5%
forbs(24 species)	6.1%
shrubs(3 species)	0.3%
mosses	0.2%

Hawthorn (Crataegus monogyna) was the most frequent shrub being present in all control plots, either as seedlings or as small (< 50 cm) plants. Rosa canina was present in both sub-plots of plot 1 and in one sub-plot of plot 19, but was not recorded in other plots. *Quercus robur* was only recorded in one sub-plot (13E).

Of the forbs present in the plots, *Helianthemum chamaecistus* was most abundant (17.71 g m^2), followed by *Poterium sanguisorba* (9.19 g m^2), *Filipendula vulgaris* (2.98 g m^2), *Cirsium acaulon* (2.48 g m^2), *Plantago lanceolata* (2.29 g m^2) and *Pimpinella saxifraga* (1.42 g m^2). Other species were only present as "traces".

3.3.2 Composition of plots not cut for 16 years (Table 3.17).

Individual plots not cut for 16 years differed considerable in appearance and composition. Field notes provide a picture of how they appeared in May 1987:

Plot 1. "Dense tussocky *Bromus* grassland, with 7 small hawthorns, the large hawthorn, some 1.5 m tall having been accidentally chopped down earlier in the year. *Bromus* tussocks 20-50 cm diameter, lower leaves reaching 50 cm, inflorescences 120 cm. Other species include: *Carex flacca, Centaurea nigra, C.scabiosa, Cirsium acaulon, Filipendula vulgaris, Helianthemum chamaecistus, Hypochoeris maculata, Pimpinella saxifraga, Polygala vulgaris, Poterium sanguisorba* and *Pulsatilla vulgaris.*

Plot 9. "Coarse tussocky grassland, with dense scrub. Hawthorns 100, 50, 30 cm high; *Rhamnus catharticus* 60 cm; *Rosa canina* 10 cm. Large rabbit burrow in NW corner, much bare soil. *Viola hirta* abundant. Other species: *Centaurea nigra, Filipendula vulgaris, Helianthemum, Lotus corniculatus* and *Poterium*.

Plot 13. Dense *Bromus* grassland, with occasional tufts of *Brachypodium sylvaticum*. In the western half of the plot there are 5 hawthorn bushes, reaching 170 cm in height. In the eastern half there are 2 small bushes reaching 70 cm. Thick layer of grass litter, with a dense carpet of mosses, mostly *Pseudoscleropodium purum*. Grass inflorescences 60-70 cm. *Poterium sanguisorba* frequent. Other species: *Carex flacca, Centaurea nigra, C. scabiosa, Cirsium acaulon, Galium verum, Helianthemum chamaecistus, Hypochoeris maculata* (in bud), *Leontodon hispidus, Lotus corniculatus, Polygala vulgaris* and *Primula veris.*

Plot 19. Coarse grassland, with hawthorn scrub reaching 85 cm and a single *Rosa*, to 96 cm. The following species were present: *Brachypodium sylvaticum, Carex flacca, Campanula glomerata, C. rotundifolia, Centaurea nigra, Cirsium acaulon, Filipendula vulgaris, Helianthemum chamaecistus, Leontodon hispidus, Lotus cornicualtus, Pimpinella saxifraga, Plantago lanceolata, Polygala vulgaris, Poterium sanguisorba, Primula veris, Ranunculus bulbosus, Senecio integrifolius* and *Viola hirta.*

The above ground biomass in these plots which had not been cut for 16 years consisted of:

Dead plant material,mostly grasses,	34.6%
Live grasses, mostly *Bromus erectus*	23.5%
Forbs	7.5%
Sedges	2.3%
Shrubs, mostly *Crateaegus* and *Rosa*	30.7%
Mosses	1.5%

The main change in composition since 1971 had been an increase in the proportion of shrubs and a decrease in the amount of dead material.

Of the living material, Crataegus and Bromus accounted for 82% of the above ground biomass, with substantial contributions being made by Poterium sanguisorba (3.89%), Carex flacca (3.59%), Filipendula vulgaris (3.02%), Helianthemum chamaecistus (2.22%) and Rosa canina (1.73%). Of the other 29 species recorded in these plots, none contributed 1% to the total biomass and most were only present in very small quantities (Table 3.17).

3.3.3 Composition of plots not cut for 23 years (Table 3.18).

The above ground composition of the vegetation in plots which had not been cut or managed for 23 years was highly variable, reflecting the time in the succession in which scrub had become established and possible the initial floristic composition. Taken over all plots ,the above ground vegetation consisted of:

dead plant material,mostly grasses	12.8%
live grasses	7.8%
forbs	2.1%
sedges	0.7%
shrubs	76.2%
mosses	0.4%

Crataegus monogyna was the dominant in most plots and accounted for 75.1% of the above ground vegetation: Rosa canina was also prominent, accounting for 12.3% of the total above ground vegetation. Bromus erectus formed large tussocks between the shrubs and was the third most abundant species accounting for 9.0% of the total biomass. These three species accounted for 96.45 of total biomass. Nevertheless, 28 other species were recorded in the plots (Table 3.18), although most were present in only small quantities. The most successful forbs to survive in this coarse, shrubby, grassland were Poterium sanguisorba(9.9 g m^2), Carex flacca(8.97 g m^2), Filipendula vulgaris(7.57 g m^2), Helianthemum chamaecistus(4.47 g m^2), and Viola hirta(1.69 g m^2).

3.4 EFFECTS OF RETURNING OR REMOVING NUTRIENTS ON SOIL PROPERTIES AND ON THE VEGETATION.

3.4.1 The proportion(%) of N, P, K, Ca and Mg in the vegetation.

Small sub-samples of vegetation were taken for chemical analysis from cut and finely ground material prior to it being returned to the plots. Samples were taken for 16 years (1969 and for the period 1972 to 1988, excluding 1974 and 1988), and used to estimate the amount of nutrients which were removed or returned to the plots.

The proportions of the different elements varied considerable from year to year, even when samples were taken at the same time of the year.This probable reflects different growth stages of the species making up the vegetation and the effects of climate on the proportion of dead or moribund tissue in samples.

In an attempt to separate the effects of cutting date (May, June or July), cutting frequency (cut once, twice or three times a year) and changes associated with time, data were analysed with time as a covariate. The results of ANCOVA are summarised in Table 3.19. Of the 5 chemical elements, only N showed a significant (P<0.001) change with time with a mean value of 1.93% increasing by 0.016% per year. This represents a 17% increase in the mean value over 20 years.

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. To examine these effects in greater detail, differences between cutting dates and cutting frequencies were analysed separately.

Nitrogen was the only element to show a significant trend with time, the proportion of other elements not changing significantly in the vegetation over the 24 years for which this experiment ran. However, there were significant differences in the proportion of Ca, Mg, P and N in the vegetation from plots which were cut twice a year compared to those cut three times a year (Table 3.20), plots cut more frequently generally having a higher value than those cut less frequently.

3.4.2 The quantities of nutrients removed or returned to the plots.

The quantities of elements (nutrients) removed or returned to each plot for the period 1969 to 1988 were calculated by multiplying the plot dry weight by the proportion of each element in the vegetation as determined by chemical analysis. (Appendices 1 to 5).

There were no significant differences between treatments in the total amount of nutrients removed annually (Table 3.21). Although plots cut once a year had a significantly higher total annual dry weight yield than plots cut twice or three times, the concentration of elements in the older vegetation from the cut once plots is less than that of the more frequently cut plots and the lower dry weight yield is compensated by the higher concentration of elements in the more frequently cut plots. Thus in plots cut once a year, all of the annual nutrient removal is completed in May, whereas for plots cut twice a year, about 75% is removed in May, the remainder in June. For plots cut three times a year. About 64% of nutrients are removed in May, 20% in June and the remainder in July.

Since the amount of nutrients removed or replaced is closely related to the productivity of the vegetation in any particular year there were significant differences in the quantities of elements removed between different years. Thus the year in which the least amount of nutrients were removed from the plots was 1976, when production reached an all time low following the drought and conversely were highest in 1972 when yields were highest.

3.4.3 Effects on soil nutrients of removing or returning plant material.

Soil samples were taken from all plots in 1973 and 1987 to estimate the long term effects of cutting, with and without the return of cut material, on the chemical status of the soil. The 1973 analysis was made by the Pedology Section, Bangor and the 1987 samples were analysed by the Chemical Section, Merlewood. Although the same methods of analysis were employed by both laboratories, between year comparisons for extractable sodium should be treated with caution, as the values obtained for the two years differ widely and are probably attributable to the method of analysis rather than being a "real" difference in the amount of sodium present.

3.4.3.1 Effect of cutting treatments on soil nutrients.

1973 Analysis.

There was no significant difference in pH, organic matter content(LOI) and extractable potassium in soil from any treatment(Table 3.22) eight years after the experiment began.

The soil %N in control plots (not cut for 8 years) was significantly less ($p<0.001$) than in cut plots (0.70 as compared with 0.74 and 0.73%).

The sodium and magnesium content of soils in the control plots was also significantly higher in the control plots (Table 3.22) than in cut plots.

The phosporus and manganese content of soils in the control plots did not differ significantly from that in plots cut twice and three times a year, although plots cut once a year did contain significantly more P and Mn than plots receiving other treatments.

1987 Analysis (Table 3.23).

This analysis enables comparisons to be made between plots which have (a) not been cut for 23 years--"control" plots, (b) Plots which were last cut in 1971 and hence it is 16 years since they were last cut, (c) plots which have been cut annually in May for 23 years, (d) plots which have been cut annually in May and June for 23 years and (e) plots which have been cut annually in May, June and July for 23 years.

Plots which had been cut annually had significantly ($p<0.001$) higher organic matter content than either control plots or plots last cut in 1971. It seems likely that returning the cut vegetation in a finely divided form enables the organic matter to be incorporated into the soil more quickly than in control plots where dead plant material has to be broken down into smaller parts by invertebrates and microorganisms before it is incorporated into the soil.

Plots which were cut annually also had significantly more K, Mn and Na than either control plots or plots last cut in 1971.

Although there were also significant differences between plots in pH, Mg, P and N, the biological interpretation of some of these differences is not clear.

pH values varied from 7.77 in plots which had not been cut for 16 years to 7.82 in plots cut once and three times a year. Plots which had not been cut for 23 years had a pH of 7.89. Such small differences are not likely to be of any biological significance in a system which is saturated with Ca ions.

Magnesium was significantly ($p<0.01$) more abundant in the control, plots not cut for 16 years and plots cut once a year annually than in plots cut twice and three times a year.

No reasonable explanation can be made to account for why the phosphorus values are highest in plots cut twice a year and in plots not cut for 16 years, whereas they are lowest in plots cut once and three times a year.

There were no significant differences between the N content of the soils in the cut or control plots (0.72 to 0.74%); surprisingly, the N value in the plots last cut 16 years previously was significantly lower than in other plots.

3.4.3.2 Effect of removing or returning cut material on soil pH, organic matter content and selected chemical elements.

In 1973, 9 years after the experiment began, there was no significant differences in the organic matter content, K and Mg status of soils to which cut material had been returned compared to those from which it had been removed. In contrast, the Mn, P and N soil values were significantly higher in plots to which cut material had been returned (Table 3.24). pH was significantly higher in plots from which plant material had been removed.

In 1987, 23 years after the experiment began, the situation was as follows (Table 3.24): no significant difference in pH (7.81 in return plots, 7.82 in remove plots), organic matter content (15.48, as against 15.11), phosphorus (1.68 and 1.62) or nitrogen (0.73 and 0.72).

Significantly more sodium, manganese and magnesium was recorded in plots from which vegetation removed than returned (Na, 8.93 and 8.49, Mn 24.85 and 23.18, Mg 24.85 and 23.18 respectively). Levels of potassium were significantly ($p<0.05$) higher in plots to which cut material was returned than in those from which it was removed.

3.5 EFFECTS OF CUTTING TREATMENTS AND NO MANAGEMENT ON FLOWERING

An assessment of the long-term effects of the various cutting treatments on flowering was made in May (prior to the first cutting) and later in August 1988, immediately before the third cutting took place. Inflorescences of all species in flower were counted in all plots, except for Asperula cynanchica, Linum catharticum and Thymus pulegioides, for which it was not practical to count individual inflorescences; instead, flowering was scored on a four point scale (rare, occasional, frequent or abundant). Special attention was given to Bromus erectus in 1987 and 1988. Inflorescences were both counted and weighed after clipping, with the objective of finding out if clipping had any effect on individual tiller dry weight. All results were subjected to ANOVA after transformation (square root(x+1)).

3.5.1 **Results from May 1988**

The counts made in May provide an estimate of the effect of the previous years treatments on flowering. Of the 18 species recorded, three (Carex flacca, Filipendula vulgaris and Sanguisorba minor) had significantly ($p<0.001$) more inflorescences in plots not cut for 24 or 17 years than in plots cut annually. Seven species (Carex caryophyllea, Hieracium pilosella, Hippocrepis comosa, Leucanthemum vulgare, Polygala vulgaris, Ranunculus bulbosus and Senecio integrifolius had significantly more flowers in plots cut annually (Table 3.25). Eight species, mostly with low frequencies, did not show a preference for any particular treatment.

Asperula, Linum and Thymus flowered much more profusely in plots that were cut three times or twice a year than in other plots, although all three species were recorded in flower in the other plots.

There was no evidence that flowering was influenced by the return or removal of cuttings.

3.5.2 Results from August 1988

The counts made in August identifies those species which are able to flower later in the year despite having been cut earlier in the year or those which escaped having inflorescences cut because they are produced later in the year. Of the 23 species recorded (Table 3.26), 10 showed a significant effect of treatment. Inflorescences of Centaurea nigra and Helianthemum chamaecistus were more frequent in control plots (not cut for 17 or 23 years) than in plots cut annually. Eight species (Campanula glomerata, C. rotundifolia, Leontodon hispidus, Lotus corniculatus, Picris hieracioides, Plantago lanceolata, Scabiosa columbaria and Sonchus asper) had more flowers in plots cut annually than in control plots.

Asperula, Linum and Thymus were again more floriferous in plots cut annually than in other plots.

3.5.3 Effect of treatments on Bromus inflorescences. (Table 3.27)

Cutting three times a year significantly ($p<0.001$) reduced the number of inflorescences of Bromus erectus compared with other cutting frequencies. However, plots cut once and twice a year did not differ significantly in the number of tillers compared with uncut controls.

Inflorescences in plots not cut for 17 and 23 years were significantly larger and had a greater mean weight per tiller than in plots cut annually.

In 1988, plots cut three times a year again had significantly fewer tillers (p = <0.05) than plots cut once or twice a year. Individual tillers were also smaller and weighed less.

The results from these two years also show that the number of tillers varies considerable from year to year, probably in response to differences in weather conditions in the previous year.

Cutting only once a year prevents the formation of large, competitive tussocks of <u>Bromus erectus</u> which are such a prominent feature of unmanaged grasslands. Cutting more than once a year further reduces tiller numbers, the third cut in July having a major effect on tiller numbers the following year, reducing significantly the competitive powers of <u>Bromus</u>.

4. DISCUSSION

Without management, chalk grassland is invaded by scrub, coarse grasses increase and the succession to woodland takes place. In Britain, chalk grasslands have traditionally been grazed by either sheep, cattle or a combination of the two, depending on the system of agriculture operating at a particular point in time. Management probably varied considerable from year to year in response to market conditions , the growth of the sward and the availability of livestock. The diverse and species-rich grassland, now much prized by nature conservationists, was created by, and maintained as part of an agricultural system using grazing animals.

Using grazing animals for managing nature reserves requires skilled labour for looking after the animals, fencing, water points and a farming system which can provide housing and supplementary feed when animals are not on the reserve.These facilities are expensive and alternative methods of managing chalk grassland were sought.Mowing was an obvious alternative to grazing and experiments were laid down on the Barton Hills and at Knocking Hoe in Bedfordshire in 1963 and 1965 respectively to investigate the effects of cutting on the floristic composition on chalk grassland.

In the 6 year study on the Barton Hills(see Wells 1971 for details) in which cut material was removed from the plots, cutting once in Spring(April) was effective in reducing the competitive ability of <u>Bromus erectus</u> the dominant grass on all three soil depths while cutting three times a year, in Spring Summer and Autumn was also effective. Other species, both grasses and forbs were able to utilize the period when competition from Bromus was reduced, Briza media and Hippocrepis comosa, in particular, increasing considerably.

Twenty-four forbs were recorded from the Barton Hills plots and although the total cover of these species fluctuated from year to year no significant changes in individual species were noted in the period 1963-8 except for the following.Hippocrepis comosa, which was only common on the medium-depth soils, increased considerably in plots cut once in Spring and also in plots with combinations of cutting in Spring with other seasons of the year.It was noticeable that in these plots, where competition from Bromus was reduced, Hippocrepis assumed a more prostrate habit of growth and effectively competed with other forbs. Asperula cynanchica behaved similarly. Both species also did best in plots cut three times a year at Knocking Hoe.

Poterium sanguisorba, the most abundant forb in the plots, was clearly reduced by cutting in summer and in combinations of other treatments which included a summer cut, but was unaffected by cutting in April probably because it produced few,if any, leaves by that time of the year. The behaviour of Helianthemum varied considerable: on shallow and medium soil depths, it decreased in plots cut in Spring while on deeper soils it increased. Cutting in autumn produced a decrease on all soil depths while in plots cut in summer there were no significant changes in cover from 1963 to 1968.

The general conclusions reached from the Barton Hills experiment were that cutting was an effective substitute for grazing and, apparently, caused no loss of species from the vegetation, at least in the short term.

The experiment at Knocking Hoe, which lasted for 23 years, provides a means of testing the validity of the conclusions reached from the Barton Hills experiment. It also enables an assessment to be made of the long-term effects of returning or removing nutrients on the floristic composition of chalk grassland and on some aspects of soil chemistry.

Total annual yield of above ground dry matter varied from 71.1 g m^2 in the "drought year" of 1976 to 302.9 g m^2 in 1972, values which are broadly in agreement with production data for chalk grassland in the Netherlands (Willems, 1983).Average yields for plots cut once a year were 194 g m^2, for plots cut twice a year 176 g m^2 and for plots cut three times a year, 152 g m^2. All of these values are within the main part of Grime's humped back model(Grime 1979) and as would be expected from the model,are associated with high floristic diversity. Although the yield of plots cut once a year was greater than that in plots cut twice or three times, there were no significant differences in the number of species present in the cut plots after 23 years of the same treatments.

Plots to which clippings were returned as finely ground up material had a greater dry weight production than plots from which clippings were removed in 14 out of 24 years but there was no evidence that yields in plots from which clippings were removed were decreasing with time. Variation in yield from year to year was more correlated with weather conditions, particularly rainfall, than with treatments.

The number of species in the experiment remained remarkably constant throughout the 23 years. Of the 53 species of phanerogams recorded in the dry weight samples, 45 were present in both 1971 and 1987, the species which changed all being of low frequency or were annuals whose populations fluctuate widely from year to year. The bare areas created by the various cutting treatments were hardly ever colonised by "weed" species, only Sonchus oleraceus occasionally establishing, despite the proximity of arable crops containing a variety of chalk weeds. The bare areas in the cut plots provided niches for annuals such as Linum catharticum and Gentianella amarella and sites in which seedlings of perennials such as Poterium sanguisorba and Helianthemum chamaecistus regenerated.

The main effect of cutting was to restrict the growth and competitive ability of the dominant grass Bromus erectus. In plots cut once a year for 23 years it accounted for 79.7% of above ground dry weight, in plots cut twice a year for 71.1% and in plots cut thrice for 60.8%. As the proportion of Bromus declined, so the amount of other species increased. For example, Festuca ovina increased from 1.48% in plots cut once to 4.01% in plots cut twice to 5.65% in plots cut thrice.

Interestingly, although there were minor changes in the hierarchical position of species under the various cutting treatments, overall, the most frequent species remained much the same. For example, the following species were always in the top 10 positions: *Bromus erectus*, *Festuca ovina*, *Helianthemum chamaecistus*, *Cirsium acaulon*, *Poterium sanguisorba*, *Thymus pulegioides*, *Helictotrichon pratense*, and *Carex flacca*. This suggests that these species are adapted to a variety of management treatments and that their relative "success" is determined by their competitive abilities which in some cases will be related to their morphology and growth habit.

Some species were significantly more abundant in some treatments than others. Species which appeared to benefit most from cutting three times a year were: *Briza media*, *Festuca ovina*, *Helictotrichon pratense*, *Koeleria gracilis*, *Asperula cynanchica*, *Leucanthemum vulgare*, *Cirsium acaulon*, *Hieracium pilosella*, *Hippocrepis comosa*, *Leontodon hispidus*, *Linum catharticum*, *Plantago media*, *Polygala vulgaris*, *Ranunculus bulbosus*, *Succisa pratensis* and *Thymus pulegioides*. Many of these species are low growing, mat-forming species or are species with a prostrate habit of growth, which benefit from the removal of taller vegetation.

In the short term, only one species(*Galium verum*)showed a response to the return of nutrients but after 23 years, 16 species were either more abundant in plots to which cuttings were returned(9 species)or were more frequent in plots to which nutrients were removed(7 species). How these data should be interpreted is not clear, particularly as chalk grassland is renowned for the limited amounts of N and P available to plants and it is hard to think of a mechanism which would result in species responding to the removal of nutrients which were already in short supply.

There is no evidence that returning material in a finely ground form has any effect on species richness.Some workers (Green 1972) have argued that returning cut material results in eutrophication and a decrease in species richness, but that contention was based on cutting down a 2 m high stand of Ulex europaeus and leaving it shredded on the ground. In other words, a large, but not quantified amount of nutrients were added to the system in one dose. Not surprisingly, nitrophiles, such as Rubus idaeus and Chamaenerion angustifolia invaded the site. The amount of nutrients returned or removed from the plots at Knocking Hoe each year in cut vegetation amounted to 2.66g m^2 N, 0.17 g m^2 P, 1.84 g m^2 K, 1.66 g m^2 Ca and 0.26 g m^2 Mg. These quantities are very small compared to the total nutrients held in the soil. The top 5cm of soil at Knocking Hoe is calculated to contain: 366g m^2 N, 58 g m^2 P, 11 g m^2 K,and 110 g m^2 of Mg.As the soil contains about 75% chalk, reserves of Ca ions are huge. Nitrogen is also being replaced annually by N fixing legumes such as Hippocrepis and Lotus corniculatus. There are also additions of nutrients in rainfall.Data gathered during 1966 from rainfall collections made on the Barton Hills estimated that rain contributed 0.6 g m^2 N, 0.014 g m^2 P, 0.572 g m^2 K, 2.47 g m^2 Ca and 0.20 g m^2 Mg. From these data it can be seen that the only element likely to be in short supply in the next decade or more if cut material continues to be removed might be potassium.

Analysis of the soil taken from the 0-5cm horizon in 1987, 23 years after the experiment began could not detect any significant effect of removing or returning nutrients on pH (7.82 and 7.81),organic matter(15.11 and 15.48), total P(1.62 and 1.68) and total N(0.72 and 0.73). Detectable differences in mineralizable N and sorption P were recorded by Rizand et al(1989) in a study of the same plots in May 1987. Nitrogen mineralization was higher in the untreated plots than in some treated plots, although the interpretation of this data was far from clear as nitrification rates while greater in plots cut once a year compared to the untreated plots but lower in plots cut twice a year with clippings returned. The same workers showed a reduction in P sorption,and hence a greater availability of added P in plots where clippings were returned, implying a potential improvement in phosphorus availability. They concluded that cutting is more effective in maintaining a low P status if the clippings are removed.

Cutting differs from grazing, the traditional means of managing chalk grassland, in three important respects.First, unlike grazing, it is non-selective and all plant material above the level of the cutting bar is harvested;second, nutrients are not returned in urine and dung, although they may be returned as clippings and generally are made available to the plant more slowly; third, the differential pressure applied to the turf by the feet of the grazing animal, which may be important for creating niches for germinating seeds are not created by the cutting machine. Mowing does not create the mosaic of habitat conditions which the grazing animal does which we perceive(on very little evidence) to be beneficial for maintaining plant diversity and species richness.

The results of this long-term experiment have demonstrated that cutting once a year in May will maintain the species-richness of previously grazed chalk grassland and prevent or control the ingress of scrub and trees. Cutting more than once a year is likely to be beneficial in maintaining the fine-grained texture(and maximum species diversity) of the grassland. There is also some evidence that rosette hemicryptophytes and other low growing species are likely to benefit and flower more profusely.

The return of clippings in a finely divided form does not seem to have an adverse effect on species composition, although this may not be the case if the productivity of the grassland is high(greater than 350 g m2 year) and the clippings have a smothering effect. On the basis of the results from the Knocking Hoe and Barton Hills experiments mowing can be recommended as an alternative management tool for certain types of chalk grassland where grazing is not possible.