Journal of Insect Conservation (2005) 9:363–374
DOI 10.1007/s10841-005-8825-8

The success of a rotational grazing system in conserving the diversity of chalk grassland Auchenorrhyncha

M.G. Morris[1,2,*], R.T. Clarke[2,3] and W.E. Rispin[2,3]
*[1]Scientific Associate, The Natural History Museum, Cromwell Road, London SW7 5BD, UK; [2]Formerly Furzebrook Research Station, Wareham, Dorset BH20 5AS, UK; [3]Centre for Ecology and Hydrology Dorset, Winfrith, Technology Centre, Winfrith Newburgh, Dorchester, Dorset DT2 8ZD, UK; *Author for correspondence: Present address: Orchard House, 7 Clarence Road, Dorchester, Dorset DT1 2HF, UK (e-mail: mgmorris.ent@virgin.net)*

Received 16 March 2005; accepted in revised form 17 June 2005

Key words: Auchenorrhyncha, Chalk grassland, Hillside position, Rotational grazing, Vegetation height

Abstract

A complex rotational grazing trial on a south-facing slope of chalk grassland at the Old Winchester Hill National Nature Reserve is briefly introduced. The responses of 23 numerous species of Auchenorrhyncha, and of species richness (S) and total abundance (N), from 1981 to 1985 are described. The greatest effects were those of variation between years, between positions on the hillside (top, middle and bottom) and between grazing plots within these positions. 10 (of the total of 23) species favoured the top of the slope, where the vegetation was significantly taller than in the middle or at the bottom. S, N and the numbers of 8 species were significantly lower on plots grazed in the year of sampling compared with ungrazed plots. Early (vs. late) grazing significantly reduced S, N and the abundance of two species, but increased the numbers of *Macrosteles laevis*. S, N and the abundance of 13 species was significantly and positively correlated with vegetation height measured early (May–June) and late (July–October); the numbers of 4 other species were so correlated with the latter height only. The significance of the results is discussed in relation to the management of grassland nature reserves for the maintenance of high invertebrate diversity. It is concluded that rotational management is an important and valuable system, but suggested that such systems should be as simple as possible whilst remaining adequate to achieve conservation objectives.

Introduction

Auchenorrhyncha are particularly useful animals for assessing the effects of grassland management because they respond to both floristic and structural characteristics of the sward and occur in good numbers of both species and individuals in most grasslands (Andrezejewska 1965; Morris 1971, 1981a, b; Waloff 1980; Brown et a1. 1992). Most species feed on grasses (Prestidge and McNeill 1983) or sedges (Nickel 2003) although a few are associated with dicotyledenous plants. As well as constituting part of the diversity of grassland invertebrates they also demonstrate some of the responses to be expected from a range of factors influencing invertebrate abundance on grasslands. In this paper nomenclature of species of Auchenorrhyncha follows Le Quesne and Payne (1981).

The response of Auchenorrhyncha to grazing (Morris 1971; Brown et al. 1992), cutting (Morris 1981a) and burning (Morris 1975) is usually negative, but positive effects are also found, particularly on *Macrosteles laevis* (Andrezejewska 1962) but also on other species (Morris 1981b). However, cessation of mowing management was found to increase species richness and abundance of individuals on an oolitic limestone grassland (Morris and Plant 1983).

Ecological field experiments have often to be established under near-uniform conditions which are unlike those on actual nature reserves. There is, therefore, frequent difficulty in translating the results of field experiments into practical management of reserves. Few reserves can offer facilities for well-replicated experiments, particularly where enclosures for grazing livestock may be required. For this reason, even when a reserve can include investigations into the effects of management these are likely to be trials rather than formal experiments with randomised and replicated treatments. The statistical analysis of the results from management trials can be difficult in the absence of a formal experimental design and lack of replication.

In this paper we describe the analysis of results from sampling Auchenorrhyncha in a rotational management trial at Old Winchester Hill, Hampshire, England, an important chalk grassland National Nature Reserve administered by English Nature.

Site and methods

Study area

The Old Winchester Hill reserve consists of 80 ha chalk grassland of which only the south-facing slope below an Iron Age fort was managed by rotational grazing. The site comprised 12 paddocks of which numbers 1–3, on the western side of the site, were permanently fenced (Figure 1). Paddock number 3 was almost all scrub, but

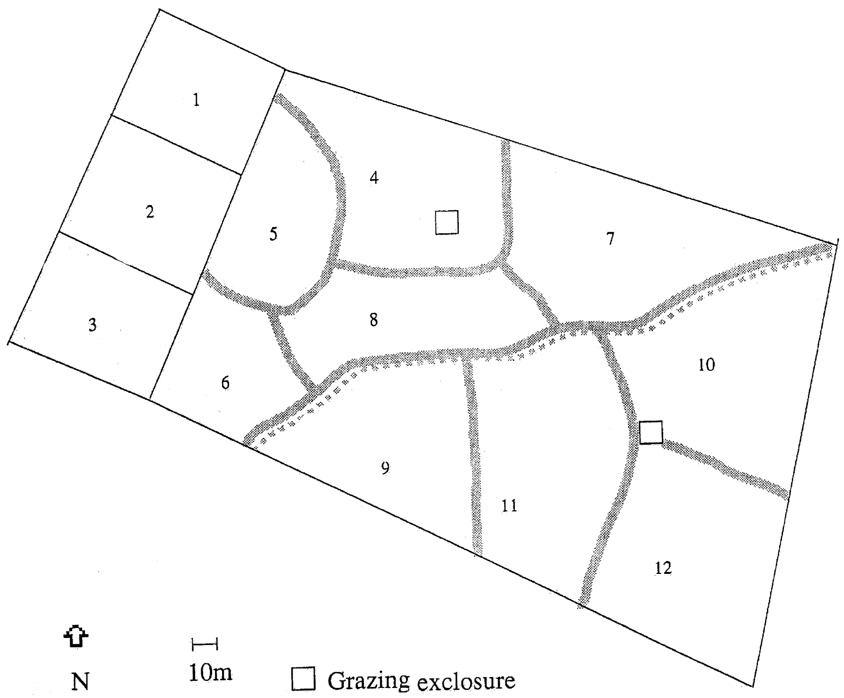

Figure 1. Layout of plots at Old Winchester Hill: 1–3 permanently fenced; 4–12 temporarily fenced for rotational grazing management.

numbers 1 and 2 had been kept clear of bushes and were included in the Auchenorrhyncha sampling programme. The remaining nine paddocks were temporarily fenced with flexi-netting when grazed.

Management

The management of the paddocks (plots) was based on a 9-year cycle, with grazing by sheep for different periods in five of the years, followed by 4 years without grazing (Table 1). The cycle started in 1981. The stocking rate varied, being designed to remove 75–100% of the available herbage during each grazing period. Holding paddocks on other parts of the reserve were used to contain the sheep when they were not required for conservation management.

The management system was designed, in part, for the conservation of Juniper, *Juniperus communis* L., a species of conservation importance on the site. The system also proved to be appropriate, though not ideal, for conservation management of the Adonis Blue butterfly, *Lysandra bellargus* (Rott.), which was re-established on the site in 1981 (Thomas 1987) and persisted for 17 generations.

Sampling

Auchenorrhyncha were sampled (together with other invertebrates) by vacuum insect net on 38 occasions from 1981 to 1985. Samples were taken throughout the four complete summer seasons 1982–1985 and also during the winter 1984–1985; however, the winter data could not be satisfactorily analysed statistically and have been excluded from this account. Each complete summer's sampling programme consisted of 7 separate samples taken regularly between late May and early October. The frequency of sampling was 2–3 weeks. The vacuum net catches were killed in the field, stored in a laboratory cold room, and sorted and identified at a later date. Only adult Auchenorrhyncha were identified and recorded.

In each of the paddocks 1, 2 and 4–12 two standard samples from c. 1.1 m^2 grassland were taken on each sampling occasion. Each sample consisted of 12 'sucks' of the vacuum insect net, the sampling head being held in position for c. 10 s. The height of the vegetation at every sample site was also recorded on each sampling occasion, by averaging four measurements made with a ruler placed upright in the sward. These figures were averaged to give values for the early part of the

Table 1. (A) The sequence of management of the Old Winchester Htill site showing the Standard 9-year cycle. (B) The rotational treatment of each plot (numbers 1 and 2 not included in the formal trial).

(A)	Year	Management	
	1	Grazing March/April + scrub clearance in April	
	2	Grazing May/June	
	3	Grazing May/June	
	4	Grazing July–September	
	5	Grazing October–December	
	6	None	
	7	None	
	8	None	
	9	None	
(B)	Plot	Starting year of management cycle	Years grazed over Period 1982–1985
	1	–	
	2	–	0
	4	5	1
	5	8	2
	6	2	4
	7	7	1
	8	4	2
	9	6	0
	10	1	4
	11	9	3
	12	3	3

season (up to the end of June – Height 1) and the later half (July–September – Height 2).

Statistical analysis

The assumption was made that, by the time sampling began in 1982 (1-year after the start of the management cycle) the system had stabilised from its previous condition with no major remaining effects.

Preliminary analyses of variance (ANOVA) showed that the variation in Auchenorrhyncha between the two samples from each plot was always small compared to the overall variation between plots, years and management regimes, so all subsequent analyses were based on combined sample fauna for each plot on each date.

Ideally, the fauna on each sampling occasion would be used to assess the effects of the management regimes on the seasonal variation in the faunas. However, insufficient individuals of enough species were taken on each date to justify quantitative analysis of abundance. The analyses were therefore based on the total numbers of species and individuals found each year in each of the plots, which were treated as separate 'plot-year' observations. The aim was then to assess the extent to which the annual total fauna on each plot varied consistently between plots (averaged over years), between years (summed over plots), and as a result of the management cycle.

The same number of plots were grazed for the same combination of months during each year of the study period (Table 1). This meant that any apparent overall differences in fauna between years were independent of, and not influenced by, any effects of the grazing regime. In contrast, the plots were grazed for varying numbers of years during 1982–1985 (Table lB), so that grazing effects and true plot differences in fauna were confounded to some extent. Plot differences were therefore tested for by allowing for grazing effects and *vice versa*. Influences of position on the hillside on plot differences were assessed by nested ANOVA, grouping the plots into 'top' (plots l, 4 and 7), 'middle' (plots 2, 5, 8 and 10) and 'bottom' (plots 6, 9, 11 and 12).

The following major aspects of the effect of the grazing regime were assessed:

(i) Grazing at any time in the current year (year in which samples were taken).

(ii) Differences between grazing *early* (March–July) and *late* (July–December). It was thought likely that grazing late in a year would influence the total catch for a year less than grazing early.

(iii) Residual effects of grazing in the previous year. Auchenorrhyncha might be more numerous *this* year if the plot had not been glazed *last* year. This was assessed separately for plots grazed, and not grazed, in the current year.

As grazing obviously reduced the height of the vegetation, direct relationships between Auchenorrhyncha and the average height of the vegetation in each plot for the two periods March–June (Height 1) and July–October (Height 2) were also assessed by separate multiple regression.

All ANOVA were done simultaneously using a multiple regression approach, based on the log $(n+1)$ transformed data. Only the most abundant species could be analysed in this quantitative way. We adopted the arbitrary standard of only analysing those species taken as 100 or more individuals over the 4 years of sampling. In addition, influences on the number of Auchenorrhyncha species (S) and their total abundance (N, as log $(N+1)$) per plot were analysed. The issue of multiple comparisons and detection of 'false positives' was not addressed.

Results

The mean height of the grassland in each plot was, of course, significantly reduced by grazing. There were also significant differences in vegetation height between positions on the hillside (Table 2) and years (Table 3). Of particular note is the decline in Height 2 on the plots ungrazed this year

Table 2. Mean height of vegetation (cm) in plots at top, middle and bottom of the hillside, with S.E. of the mean; Height 1 before end June, Height 2 July–September.

	Height 1	Height 2
Significance of difference	***	***
Top	11.6 ± 3.8	14.6 ± 3.7
Middle	7.1 ± 3.8	8.2 ± 3.7
Bottom	6.1 ± 3.8	8.1 ± 4.5

***$p < 0.001$.

but grazed last year over the period of sampling, though the significance of this was not tested.

Of 63 species of Auchenorrhyncha recorded during the sampling period 23 were taken as 100 individual or more (Table 4). The females of *Macrosteles* spp. could not be distinguished and were aggregated and treated separately. The 23 abundant species mostly occurred at least once on each plot but *Arocephalus punctum*, *Paluda adumbrata*, *Mocydia crocea*, *Arboridia parvula*, *Delphacinus mesomelas*, *Hyledelphax elegantulus* and *Kosswigianella exigua* were absent from some plots.

Mean species richness per plot per year (S) was significantly affected by all the factors examined except that there was no effect on plots grazed in the previous, but not the current, year (Table 4). Overall abundance of individuals (N) was significantly affected by years, position on the hillside, and grazing in the year of sampling, particularly early grazing (Table 4).

The commonest significant effects on the abundance of individual species were those of years and plots within the hillside positions. Only *Eupelix cuspidata* was affected by neither and 11 species were affected by both (Table 4).

S and N were lower in 1985 compared to previous years (Table 5). *Ulopa trivia*, *Agallia venosa*, *Aphrodes albifrons*, *A. bicinctus*, *Eupteryx notata* and *Hyledelphax elegantulus*, or six species out of 20, were the only ones to show consistent declines in abundance from 1982 to 1985 (Table 5). However, there was a general decline from 1982 to 1985, with *Arboridia parvula* the only species recorded as more numerous in 1985 than 1982.

Most of the species which were significantly affected by position on the hillside favoured the top of the slope (10 of 13: Table 6). In some cases this preference was pronounced, with 87% of *Paluda adumbrata* and 90% of *Delphacinus mesomelas* recorded in this position. This marked effect of the top of the slope was reflected in the significantly greater species richness (S) and abundance of individuals (N) recorded there.

Nevertheless, some species were significantly more numerous in the middle of the slope (*Neophilaenus exclamationis* and *Ulopa trivia*) or at its bottom, where 80% of *Hyledelphax elegantulus* were recorded.

A simple cernparison of grazed and ungrazed plots showed that S, N and the abundance of 8 species were significantly greater on the latter (Table 7); no significant positive effect of grazed vs. ungrazed plots was recorded for numbers of *Macrosteles laevis* when no distinction between early and late grazing was made.

However, grazing early in the year favoured *Macrosteles laevis*, but reduced S, N and the numbers of *Ulopa trivia* and *Eupteryx notata* compared with no grazing and late grazing, with the latter less damaging than the former (Table 8).

Five species, together with S showed significant effects of grazing in the year before sampling, when grazed in the current year (Table 9). In all cases grazing in both years had the most severe effects on numbers, with the reduction of *Kelisia guttula* and *K. vittipennis* particularly marked. In each case except *K. vittipennis* the highest numbers were recorded in the plots receiving no management in either year.

Table 3. Mean height of vegetation (cm) in each year on plots grazed or ungrazed this year, and last year, Height 1 before end June, Height 2 July–September.

	This year	Grazed		Ungrazed	
	Last year	Grazed	Ungrazed	Grazed	Ungrazed
Height 1	1982	3.8	1.0	4.0	11.2
	1983	7.8	8.7	10.5	13.0
	1984	4.4	4.8	8.4	12.7
	1985	3.8	4.5	4.0	10.0
Height 2	1982	6.3	5.2	11.4	15.0
	1983	5.2	13.4	14.7	15.1
	1984	5.5	6.9	8.9	13.9
	1985	5.6	5.3	5.7	12.4

Differences between years significant at $p < 0.001$ for both Heights.

Table 4. Auchenorrhyncha (vacuum net samples). Significance of effects recorded for abundant species (>100 individuals).

Species	Effect of years	Hillside position (Top, Middle, Bottom)	Plot within hillside position	Grazing this year	Grazing last year when this year is		Early vs. late grazing
					Grazed	Not grazed	
Number of species	***	***	*	**	*	NS	***
Number of individuals	***	*	NS	***	NS	NS	**
Neophilaenus exclamationis	NS	***	***	NS	NS	NS	NS
Ulopa trivia	***	**	*	NS	*	NS	*
Agallia venosa	***	**	***	NS	NS	NS	NS
Eupelix cuspidata	NS	NS	NS	NS	NS	NS	NS
Aphrodes albifrons	***	*	NS	NS	NS	NS	NS
Aphrodes bicinctus	***	*	NS	NS	NS	NS	NS
Arocephalus punctum	**	***	***	**	NS	NS	NS
Turrutus socialis	**	NS	*	NS	NS	NS	NS
Rhytistylus proceps	*	NS	**	**	NS	NS	NS
Paluda adumbrata	*	***	***	NS	NS	NS	NS
Mocydia crocea	*	NS	***	NS	NS	NS	NS
Mocydiopsis attenuata	**	NS	NS	**	NS	NS	NS
Macrosteles laevis	***	NS	*	NS	NS	NS	*
Macrosteles sexnotatus	***	NS	NS	NS	NS	NS	NS
Macrosteles (females)	**	NS	NS	*	NS	NS	NS
Eupteryx notata	***	NS	*	***	NS	NS	*
Zyginidia scutellaris	***	***	***	**	NS	**	NS
Arboridia parvula	***	*	***	*	NS	NS	NS
Kelisia guttata	***	**	**	***	NS	*	NS
Kelisia vittipennis	***	*	***	**	NS	*	NS
Delphacinus mesomelas	NS	***	*	NS	NS	*	NS
Hyledelphax elegantulus	*	***	*	NS	NS	NS	NS
Javesella pellucida	***	NS	*	NS	NS	NS	NS
Kosswigianella exigua	*	NS	***	NS	NS	NS	NS

*, **, *** denote significance at the 5, 1 and 0.1% probability levels respectively.
NS, not significant.

Both S and N were very highly correlated with average vegetation height in both March–June (Height 1) and July–October (Height 2) (Table 10). The abundance of 14 species was also significantly correlated with sward height in both periods The numbers of a further four species were correlated with mean vegetation height during the second period (Height 2) but not the first (Height 1). Apart from *Macrosteles laevis*, the abundance of which was significantly but negatively correlated with sward height, and the numbers of female *Macrosteles*, which were negatively but not significantly so correlated, the abundances of all species were positively correlated. There is thus overwhelming evidence for a beneficial effect of relief from grazing on the numbers of most species of grassland Auchenorrhyncha.

Four species recorded during 1982–1985 are 'Nationally Notable' (Kirby 1992). *Scleroracus decumanus* and *Ribautodelphax angulosus* were recorded as only one and two individuals respectively. The effects of slope position and grazing on numbers of *Ulopa trivia* have already been discussed. *Tettigometra impressopunctata* was recorded as 40 individuals. It was distributed mainly in the western part of the slope and was not found in plots 4, 7, 10 or 11.60% of the specimens were taken in the ungrazed plots 1 and 2.

Discussion

Site factors have been shown to be of particular importance in determining the composition of the Auchenorrhyncha faunas of calcareous grasslands (Morris 1990). Total samples from the same sites in different years tended to be similar, with samples from different sites, even in the same years, tending to be less closely related. The faunas examined included those from Old Winchester

Table 5. Auchenorrhyncha (vacuum net samples). Annual means and standard errors (SE) for species which differed significantly between years. Symbols for significance as Table 4.

	1982		1983		1984		1985		Significances
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	
Number of species	24.7	5.2	23.9	4.5	24.6	5.8	17.0	4.7	***
Number of individuals	802.5	399.0	575.5	291.6	616.8	397.1	270.2	133.7	***
Ulopa trivia	34.8	22.1	23.8	11.3	23.5	10.0	11.8	6.0	***
Agallia venosa	57.4	43.1	55.4	48.3	38.2	40.7	27.1	23.9	***
Aphrodes albifrons	5.8	5.5	1.9	1.9	1.1	1.2	0.4	0.9	***
Aphrodes bicinctus	10.5	8.6	5.4	5.0	1.4	1.7	0.5	1.0	***
Arocephalus punctum	9.6	12.1	9.6	10.6	16.5	19.4	5.9	8.5	**
Turrutus socialis	122.6	87.7	123.1	83.4	146.1	78.0	63.1	35.1	**
Rhytistylus proceps	55.7	57.6	38.5	30.2	52.3	53.2	16.2	10.6	*
Paluda adumbrata	5.2	9.9	6.2	11.5	13.8	37.1	2.0	6.0	*
Mocydia crocea	3.5	6.0	3.9	5.1	3.3	6.4	0.6	1.3	*
Mocydiopsis attenuata	4.4	7.6	4.6	4.2	10.3	12.6	1.7	3.9	**
Macrosteles laevis	11.6	15.1	1.0	2.4	4.3	3.5	0.8	1.0	***
Macrosteles sexnotatus	55.5	115.4	0.5	0.7	1.2	1.6	0.0	0.0	***
Macrosteles females	4.0	3.6	2.0	1.5	1.5	1.6	0.4	0.7	**
Eupteryx notata	182.0	126.2	80.4	66.8	36.0	29.6	33.9	33.4	***
Zyginidia scutellaris	158.4	172.3	83.1	115.5	92.9	116.7	28.5	49.4	***
Arboridia parvula	6.0	8.1	18.7	29.2	49.5	80.1	28.1	23.2	***
Kelisia guttula	7.3	7.7	25.7	24.5	20.3	21.4	4.4	6.0	***
Kelisia vittipennis	20.4	27.1	53.1	70.2	47.8	75.6	10.8	23.8	***
Hyledelphax elegantulus	10.3	17.0	7.0	12.4	2.7	5.7	1.8	4.5	*
Javesella pellucida	7.2	6.2	1.7	1.2	2.4	4.0	5.6	3.4	***
Kosswigianella exigua	7.7	12.2	5.7	11.6	18.0	43.9	3.9	8.7	*

Table 6. Auchonorrhyncha (vacuum net samples). Means and standard errors (SE) for species which differed significantly between position on the hillside (top, middle and bottom); symbols as in Table 4.

	Top		Middle		Bottom		Significance
	Mean	SE	Mean	SE	Mean	SE	
Number of species	27.3	5.6	20.6	4.4	21.0	5.8	***
Number of individuals	831.4	391.8	548.6	324.9	384.7	277.8	*
Neophilaenus exclamationis	6.9	6.5	12.0	19.6	2.2	3.4	***
Ulopa trivia	18.1	10.8	29.2	20.2	21.9	1.9	**
Agallia venosa	67.1	52.8	46.3	38.8	25.8	20.2	**
Aphrodes albifrons	3.6	3.1	1.3	1.7	2.3	4.9	*
Aphrodes bicinctus	7.3	8.3	2.6	4.5	4.1	5.7	*
Arocephalus punctum	16.2	13.3	13.0	16.0	3.6	6.7	***
Paluda adumbrata	20.9	35.1	1.4	3.3	1.6	3.9	***
Zyginidia scutellaris	145.0	142.2	120.4	147.6	20.3	20.9	***
Arboridia parvula	64.6	72.5	15.8	15.3	6.1	13.0	*
Kelisia guttula	28.8	26.7	12.3	14.1	5.7	5.3	**
Kelisia vittipennis	63.5	78.8	37.1	52.5	6.1	7.3	*
Delphacinus mesomelas	9.3	12.0	0.1	0.3	0.9	3.0	***
Hyledelphax elegantulus	1.0	1.8	2.1	3.7	12.2	16.5	***

Hill, but only those recorded in 1982 and 1983 (Morris 1990). It is therefore of especial interest that variation between years should have been so great when the full data set (1982–1985) was analysed (Tables 4 and 5). The effects of year-to-year variation, and differences between plots, are clearly of relevance to the maintenance of diversity of Auchenorrhyncha, even though the differences

Table 7. Auchenorrhyncha (vacuum net samples). Effects of grazing (current year; no distinction between grazing periods). Means and SE for species with significant differences; symbols as in Table 4.

	Grazed		Ungrazed		Significance
	Mean	SE	Mean	SE	
Number of species	19.2	4.6	25.7	5.3	**
Number of individuals	362.9	209.3	751.7	385.5	***
Arocephalus punctum	10.2	15.6	10.7	11.4	**
Rhytistylus proceps	26.1	25.4	53.9	52.7	**
Mocydiopsis attenuata	1.1	2.3	9.0	9.8	**
Eupteryx notata	54.6	61.2	109.1	111.8	***
Zyginidia scutellaris	25.8	37.9	150.0	148.7	**
Arboridia parvula	6.5	12.7	43.0	57.2	*
Kelisia guttula	7.9	15.0	20.4	20.0	***
Kelisia vittipennis	12.6	37.9	51.7	63.2	**

do not relate directly to conservation management. However, the overall decline in the numbers of many species from 1982 to 1985 is likely to be at least partly related to the decline in mean height of the sward over this period, though the statistical significance of the decline was not tested (Table 3).

The importance of the top of the slope for most of the species which showed significant differences in abundance in relation to position on the hillside was also of particular interest (Table 6). Although no species was entirely absent from any of three slope positions several were not recorded froth some plots. Thus *Paluda adumbrata* was absent from two plots in each of the middle and bottom sections and *Delphacinus mesomelas* from two in the middle section and three at the bottom of the slope. *Hyledelphax elegantulus* was not recorded from two plots at the top and one in the middle of the site. The hilliside positions are not absolute because of the configuration of the grazing paddocks. The preference of Auchenorrhyncha for the top of the site was related to the taller vegetation there (Table 2). This has importance in the integratation of other conservation interests into the management of the reserve. Maintenance of Juniper and the re-established Adonis Blue butterfly could be concentrated in the middle and bottom areas of the site. The top plots were generally less suitable for the latter species (Thomas 1987) because of the taller vegetation there.

The simple effect of grazing in the year of sampling was to reduce S and N and the numbers of eight species (Table 7). No species responded positively to this simple effect. This is in general agreement with previous work of management effects (Morris 1971, 1981a) as well as the preponderance of positive correlations of species abundance with vegetation height, there being 18 species whose abundance was significantly correlated with at least one sward height and only 5 (excluding *Macrosteles* females) where the relationship was not significant (Table 10). The importance of tall, unmanaged grassland for the conservation of diversity of Auchenorrhyncha is thus confirmed.

Table 8. Auchenorrhyncha (vacuum net samples). Effects of grazing (current year); ungrazed, early grazed (March–June) and late-grazed (July–October). Means and SE for species with significant differences; symbols as in Table 4.

	Ungrazed		Early grazed		Late grazed		Significance
	Mean	SE	Mean	SE	Mean	SE	
Number of species	25.7	5.3	18.2	4.7	20.8	4.1	***
Number of individuals	751.7	385.5	325.2	215.6	424.0	196.5	**
Ulopa trivia	29.0	18.1	16.0	7.8	19.9	12.0	*
Macrosteles laevis	2.3	3.9	9.5	14.3	2.1	2.4	*
Eupteryx notata	109.1	111.8	39.4	40.6	79.3	82.3	*

Table 9. Auchenorrhyncha (vacuum net samples). Effects of grazing in year previous to sampling (last year), separately for plots grazed and ungrazed this year. Means for species with significant differences; symbols as in Table 4.

This year	Grazed			Ungrazed		
Last year	Grazed	Ungrazed		Grazed	Ungrazed	
	Mean	Mean	Significance	Mean	Mean	Significance
Number of species	14.8	16.8	NS	18.9	21.1	*
Ulopa trivia	8.3	10.1	NS	10.1	15.7	*
Zyginidia scutellaris	10.8	19.8	NS	17.3	91.0	**
Kelisia guttula	2.3	9.1	NS	8.5	10.7	*
Kelisia vittipennis	1.5	21.7	NS	26.9	25.5	*
Delphacinus mesomelas	0.2	1.5	NS	0.8	2.8	*

Table 10. Auchenorrhyncha (vacuum net samples). Spearman rank correlation coefficients (r_S) and their significance between number of species, abundances and sward height in March–June (Height 1) and July–October (Height 2). Symbols for significance as in Table 4.

	Height 1		Height 2	
	r_S	Significance	r_S	Significance
Number of species	0.68	***	0.80	***
Number of individuals	0.62	***	0.72	***
Neophilaenus exclamationis	0.17	NS	0.13	NS
Ulopa trivia	0.19	NS	0.27	NS
Agallia venosa	0.57	***	0.69	***
Eupelix cuspidata	0.38	*	0.38	*
Aphrodes albifrons	0.50	***	0.60	***
Aphrodes bicinctus	0.20	NS	0.38	*
Arocephalus punctum	0.41	**	0.37	*
Turrutus socialis	0.15	NS	0.31	*
Rhytistylus proceps	0.43	**	0.56	***
Paluda adumbrata	0.44	**	0.47	**
Mocydia crocea	0.41	**	0.34	*
Mocydiopsis attenuata	0.71	***	0.77	***
Macrosteles laevis	– 0.33	*	– 0.43	**
Macrosteles sexnotatus	0.06	NS	0.20	NS
Macrosteles females	– 0.24	NS	– 0.17	NS
Eupteryx notata	0.27	NS	0.33	*
Zyginidia scutellaris	0.61	***	0.61	***
Arboridia parvula	0.63	***	0.63	***
Kelisia guttula	0.75	***	0.68	***
Kelisia vittipennis	0.66	***	0.65	***
Delphacinus mesomelas	0.53	***	0.65	***
Hyledelphax elegantulus	0.17	NS	0.25	NS
Javesella pellucida	0.12	NS	0.30	*
Kosswigianella exigua	0.07	NS	0.10	NS

Both S and N were lower on the early grazed plots than the late grazed ones, though both treatments reduced them compared with the ungrazed plots (Table 8). On calcareous grassland managed by cutting, treatment in May was in general less deleterious than a July cut (Morris and Lakhani 1979; Morris 1981b), but the catastrophic nature of cutting compared with the more gradual effects of grazing, together with greater variation in timing, may account for the difference.

Early grazing reduced numbers of only two species of the total fauna compared with late or no grazing (Table 8). This is a small number compared to those species of affected by grazing with no distinction between late or early treatment (Table 7) or those with abundances significantly correlated with vegetation height (Table 10). On chalk grassland at Aston Rowant N.N.R. *Eupteryx notata* was more abundant in paddocks grazed in spring (April–June) and autumn (October–December) than those grazed in winter (January–March) or summer (July–September) (Morris 1973), but this species has two generations a year (Nickel 2003) which possibly accounts in part for the result. Morris (1971) found that numbers of many Auchenorrhyncha increased markedly in the second year after exclusion from intensive grazing at the Barton Hills, Bedfordshire, another chalk grassland site.

The response of *Ulopa trivia* to early grazing was interesting, as this ground-living species might have been expected to be relatively insensitive to management. However, it occurs predominantly on south-facing slopes (Morris 1972) and may be strongly affected by microclimate, particularly temperature. Grazing produces short turf with a hot microclimate (Thomas 1991). Although *Ulopa trivia* responded to slope position (Table 6), as well as to grazing, it occurred in all plots and was evenly distributed throughout the site.

The response of *Macrosteles laevis* to grassland disturbance is well known (Andrezejewska 1962) and the positive effect of early grazing was expected.

No other species was favoured by management in the year of sampling. This contrasted with the effects of cutting management on oolitic limestone grassland at Castor Hanglands N.N.R. (Morris 1981a), though the results were in part cumulative. On that site 8 species were favoured by management. Two of these were not recorded at the Old Winchester Hill site and a further three occurred as fewer than 100 individuals. One of the remaining species was *Macrosteles laevis* and another was *M. sexnotatus*; the latter species occurred small numbers at Castor Hanglands and although it was more abundant on cut plots than uncut ones the differences were not significant. The other species affected at Castor Hanglands was *Paluda adumbrata* which significantly increased (as the proportion of the total numbers recorded) in 3 years of management on plots cut in May compared to uncut control plots. The difference between Castor Hanglands and the Old Winchester Hill site is likely to be related to the timing as well as the management methods. Although the species was significantly affected by slope position (Table 6), being most abundant at the top of the slope, the vegetation was tallest there; the fact that the Castor Hanglands plots were on a level site does not seem to be relevant.

The adverse effect of grazing in the year of sampling on S was increased if the plots had also been grazed in the previous year (Table 9), but not significantly. This was also generally true for the five species affected by grazing in both the current and previous years. There were some variations in the differences between plots grazed in the current year and ungrazed in the previous one, and in those ungrazed 'this year' but grazed 'last year'. However, these differences were small (Table 9). The biggest differences in abundance were recorded between plots grazed/grazed in both years and those ungrazed/ungrazed, with numbers in the latter being the greater in every case, though again not significantly so.

Little can be said about the factors which determine the presence and abundance of 'Nationally Notable' species except *Ulopa trivia* and, less certainly, *Tettigometra impressopunctata*. Both species appear to be adequately conserved by the rotational grazing system, with *T. impressopunctata* favouring unmanaged grassland. The host of *Rihautodelphax angulosus* is *Anthoxanthum odoratum* L. (den Bieman l987; Nickel 2003), but little appears to be known about the biology of *Scleroracus decumanus*.

Although the rotational management system at the Old Winchester Hill site can be judged a success, some caution needs to be exercised because of the lack of any direct comparisons with other systems, and to some extent because of the importance which the top part of the site has for Auchenorrhyncha abundance. The maintenance of tall, ungrazed grassland at the top of the slope is certainly indicated as a priority for conservation of species diversity. It is much less certain that the complexity of management is required, particularly the grazing of plots at increasingly later periods in successive years. Although management of the site may be said to be fine-tuned (Morris 1991), there is little evidence that this fine tuning benefits particular conservation priorities. On current evidence the regeneration of Juniper is unlikely to be favoured by the system (Dr L.K. Ward, pers. comm.). Nor is it ideal for conservation of the Adonis Blue butterfly, should it be decided to make a re-introduction. The site may be too small to allow for this and for conservation of species diversity of plants and invertebrates.

The simultaneous presence of tall and short grassland on one site, or at least in a group, or suite, of sites is an important requirement for conservation of groups other than Auchenorrhyncha, for example butterflies (Thomas 1990). In this context it is necessary to consider treads in time. In the current study a general reduction in sward height was apparent from 1982 to 1985 and (Thomas 1990) detected an overall decrease in 14 chalk grassland sites in South Dorset from 1978 to 1985. Such decreases may be the result of changing management. However, on sites such as Old Winchester Hill the interaction of a constant management system with sward growth, for instance in relation to weather, particularly rainfall, may produce unexpected effects. For this reason sward height may be a better guide to effective management than adherence to a particular system. Rotational management produces many desirable results and is highly recommended for the conservation of species richness and diversity (Morris 2000). However, it is only one system of several which may be appropriate under different circumstances. Extensive systems (Bacon 1990) have certain advantages, particularly where resources are limited. Moreover, rotational systems are most appropriate for maintenance management. Reclamation and creative management usually require a different approach.

Acknowledgements

Former staff of English Nature's South England Region, particularly John Bacon, are thanked for their support, interest, practical help and funding. We are grateful to Drs Lena Ward and J.A. Thomas for their contributions to this paper and for valuable discussion.

References

Andrezejewska L. 1962. *Macrostelis laevis* Rib. as an unsettlement index of natural meadow associations of Homoptera. Bull. Acad. Sci. Cl. II. Ser. Sci. Biol. 10: 221–226.

Andrezejewska L. 1965. Stratification and its dynamics in meadow communities of Auchenorhyncha (Homoptera). Ekol. Pol. Ser. A 13: 685–715.

Bacon J.C. 1990. The use of livestock in calcareous grassland management. In: Hillier S.H., Walton D.W.H. and Wells D.A. (eds), Calcareous Grasslands-Ecology and Management. Bluntisham Books, Huntingdon, pp. 121–127.

den Bieman C.F.M. 1987. Host plant relations in the planthopper genus *Ribautodelphax* (Homoptera, Delphacidae). Ecol. Entamol. 12: 163–172.

Brown V.K., Gibson C.W.D. and Kathirithamby J. 1992. Community organisation in leaf hoppers. Oikos 65: 97–106.

Kirby P. 1992. A Review of the Scarce and Threatened Hemiptera of Great Britain. JNCC, Peterborough.

Le Quesne W.J. and Payne K.R. 1981. Cicadellidae (Typhlocybinae) with a check list of the British Auchenorhyncha (Hemiptera, Homoptera). Handbk Ident. Br. Insects 2(2c): 1–95.

Morris M.G. 1971. Differences between the invertebrate faunas of grazed and ungrazed chalk grass1and IV. Abundance and diversity of Homoptera-Auchenorhyncha. J. Appl. Ecol. 8: 37–52.

Morris M.G. 1972. Distributional and ecological notes on *Ulopa trivia* Germar (Hem., Cicadellidae). Entomol. Mon. Mag. 107(1971): 174–181.

Morris M.G. 1973. The effects of seasonal grazing on the Hetoroptera and Auchenorhyncha (Hemiptera) of chalk grassland. J. Appl. Ecol. 10: 761–780.

Morris M.G. 1975. Preliminary observations on the effects of burning on the Hemiptera (Heteroptera and Auchenorhyncha) of limestone grassland. Biol. Conserv. 7: 311–319.

Morris M.G. 1981a. Responses of grassland invertebrates to management by cutting III. Adverse effects on Auchenorhyncha. J. Appl. Ecol. 18: 107–123.

Morris M.G. 1981b. Responses of grassland invertebrates to management by cutting IV. Positive responses of Auchenorhyncha. J. appl.Ecol. 18: 763–771.

Morris M.G. 1990. The Hemiptera of two sown calcareous grasslands III. Comparisons with the Auchenorhyncha faunas of other grasslands. J. Appl. Ecol. 27: 394–409.

Morris M.G. 1991. The management of reserves and protected areas. In: Spellerberg I.H., Goldsmith F.B. and Morris M.G. (eds), The Scientific Management of Temperate Communities for Conservation (31st Symposium of the British Ecological Society). Blackwell, Oxford, pp. 323–347.

Morris M.G. 2000. The effects of structure and its dynamics on the ecology and conservation of arthropods in British grasslands. Biol. Conserv. 95: 129–142.

Morris M.G. and Lakhani K.H. 1979. Responses of grassland invertebrates to management by cutting I. Species diversity of Hemiptera. J. Appl. Ecol. 16: 417–432.

Morris M.G. and Plant R. 1983. Responses of grassland invertebrates to management by cutting V. Changes following the cessation of management. J. Appl. Ecol. 20: 157–177.

Nickel H. 2003. The Leafhoppers and Planthoppers of Germany. Pensoft Publishers, Sophia-Moscow and Goecke und Evers, Keltern.

Prestidge R.A. and McNeill S. 1983. Auchenorrhyncha-host–plant interactions: leafhoppers and grasses. Ecol. Entamol. 8: 331–339.

Thomas J.A. 1987. Introductions to conserve the Adonis Blue Butterfly. Rep. Inst. Terr. Eco1. 1986(87): 95–97.

Thomas J.A. 1990. The conservation of Adonis bule and Lulworth skipper butterflies. In: Hillier S.H., Walton D.W.H. and Wells D.A. (eds), Calcareous Grasslands – Ecology and Management. Bluntisham Books, Huntingdon, pp. 112–117.

Thomas J.A. 1991. Rare species conservation: case studies of European butterflies. In: Spellerberg I.H., Goldsmith F.B. and Morris M.G. (eds), The Scientific Management of Temperate Communities for Conservation (31st Symposium of the British Ecological Society). Blackwell, Oxford, pp. 149–197.

Waloff N. 1980. Studies on grassland leathoppers (Auchenorhyncha; Homoptera) and their natural enemies. Adv. Ecol. Res. 11: 82–215.