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The effect of pasture improvement and burning on Orthoptera populations of Culm grasslands in northwest Devon, UK

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Abstract

Very little research has been conducted into the impact of grassland management on insect populations of Culm grasslands located in northwest Devon, UK. This paper presents the effects of agricultural improvement and burning on Orthoptera populations of these wet, heathy pastures at Dunsdon National Nature Reserve. The results from this 2-year study should aid conservation management of this important UK habitat. Orthoptera populations and habitat variables of improved (drained and cropped from 1840-1875) and unimproved pastures, were monitored in 2002 and 2003. There was no significant difference in Orthoptera abundance between pasture cropped from 1840-1875 and unimproved grassland, suggesting that mobile grasshopper species such as the meadow grasshopper *Chorthippus parallelus*, recolonised the improved swards from surrounding pastures, after a lengthy period of arable cropping in the 1800s. Winter burning led to higher numbers of Orthoptera in the post-burn year, perhaps due to the reduced sward height and biomass on the burnt swards, making them more favorable for postdiapause development.

Key words

grasshoppers, Orthoptera, Culm grassland, improved pasture, unimproved pasture, burning, Devon

Introduction

Culm grassland (Rhôs pasture) is a mosaic of National Vegetation Classification (NVC) communities: M16, M23, M24, M25 and M27, varying from wet heaths to rush pastures (Rodwell 1992) and is defined by Devon County Council (DCC 2000) as 'wet, often heathy grazing pasture'. The pastures are located on the poorly drained, wet, acid soils of the Culm Measures in Devon and Cornwall, UK, where fields are generally small and separated by dense hedgerows (DCC 2000).

Culm grassland is characterised by a mixture of wet heath, rush pasture, fen meadow, mire and scrub habitats, which contain an array of rare species such as marsh fritillary butterfly, *Euphydryas aurinia* and lesser butterfly orchid, *Platanthera bifolia*. Purple moor-grass, *Molinia caerulea* is the dominant grass species, prevalent in the wet soil conditions (Rodwell 1992). Many areas are designated as Sites of Special Scientific Interest (SSSIs). Recently, Culm grassland has been added to the Devon and UK Biodiversity Action Plans (UK Biodiversity Steering Group 1995, DCC 2000), reflecting the diversity and number of rare species that are present.

Culm grasslands are threatened by agricultural improvement, abandonment of grazing and fragmentation of sites. Approximately 48% of the total area of Culm grassland was destroyed between 1984 and 1991 (UK Biodiversity Steering Group 1995)—the main causative factor being agricultural improvement through drainage, ploughing, reseeding and fertiliser application (DCC 2000). These grasslands continue to be improved, although the rate of agricultural improvement has decreased in recent years. Abandonment of grazing on many of the remaining unimproved pastures has resulted in the invasion of sites by tall, rank vegetation and ultimately, succession to scrub and woodland.

Traditional Culm grassland management, such as grazing and burning, has been undertaken to restore neglected sites (Wolton 1991). Grazing of pastures usually occurs between late May and late September, at a stocking rate of approximately 1 suckler cow per ha over a period of 20 wk, leading to a diverse sward about 150 mm in height (Wolton 1991). Winter burning (or swaling) during January or February is also practiced and has traditionally been used after particularly wet summers, when it was impossible to graze livestock. This burning reduces the quantity of leaf litter, therefore providing a more open sward (Ausden & Treweek 1995).

The impact of Culm grassland management on the invertebrate fauna has not been thoroughly studied, and in particular, the effects on Orthoptera populations are unknown. Large populations of Orthoptera may be beneficial to Culm grassland ecosystems, as many declining farmland bird species (for example, Cirl Bunting *Emberiza cirlus*, Evans *et al*. 1997, Peach *et al*. 2001) and spiders (Belovsky & Slade 1993) are known to utilise Orthoptera as a food source.

Orthoptera were chosen as indicator species of favorable habitat in this study of Culm grasslands because assemblages are particularly sensitive to disturbance of the grass layer in grasslands, especially during grazing (Jepson-Innes & Bock 1989, Prendini *et al*. 1996, Chambers & Samways 1998), fire (Gillon 1972; Gandar 1982; Evans 1984, 1988) and modifications to land management regimes (*e.g.*, restoration of neglected pastures for subsequent agricultural use). Furthermore, Orthoptera were chosen because their abundance and ease of sampling allowed collected data to be analysed statistically (Stebaev 1968, Anderson 1999, Anderson *et al*. 2001, Foord *et al*. 2002).

This paper presents the results of a 2-y study into the impact of agricultural improvement and grassland burning on Orthoptera populations of an important Culm grassland site in northwest Devon, UK. The findings reported here should aid the conservation management of this declining UK habitat.

Methods

The study comprised 2 distinct parts: the monitoring of Orthoptera in improved and unimproved pastures and an investigation into the effect of grassland burning on populations of Orthoptera.

Study site.—Dunsdon National Nature Reserve (NNR, OS grid ref: SS3007) located in northwest Devon, UK, on the Culm Measures, was chosen for the study in 2002 and 2003 (Fig. 1). The Measures are underlain by carboniferous slate, shale and sandstone and the vegetation is characterised as purple moor-grass/rush pasture. Dunsdon NNR is approximately 38 ha in area and has numerous pastures that have been managed traditionally using grazing livestock for many centuries. These pastures support rare butterfly species such as *E. aurinia*.

Northwest Devon has a cool, wet oceanic climate, receiving between 900 to 1000 mm rainfall annually (*c.* 150 rain days) and approximately 1500 sunshine hours each year. Mean annual maximum and minimum temperatures are 13.8˚C and 7.5˚C respectively (Bude Weather Station 1971 – 2000, Met Office 2003).

The effect of agricultural improvement

To study the effect of agricultural improvement on Orthoptera, monitoring of insect populations and habitat was conducted in 2002 and 2003 in improved and unimproved pastures:

Improved (2 pastures, approximate area 2 ha): During the period of agricultural prosperity in the 1830s and 1840s, the pastures studied were ploughed and drained. The drainage took water away from the soil surface, whilst the excavated material resultant from the drainage created raised areas in the pastures. These areas were probably sown with oats in 1840, and arable cropping continued until approximately 1875, after which both fields were allowed to revert back to pasture by natural regeneration of vegetation. Several areas of the pastures were burnt in February 2003.

Unimproved (2 pastures, approximate area 1.5 ha): These pastures have never been agriculturally improved through ploughing, drainage or cropping to increase the productivity of the farmland. However, they have been grazed or cut for hay for many hundreds of years. Several areas of the 2 unimproved pastures were burnt in February 2003.

Sampling of Orthoptera populations.—A transect method was used to estimate the relative size of Orthoptera populations in each pasture type (Isern-Vallverdu *et al.* 1993). Each transect was walked at a slow pace (2 km/h) and the number of nymphal and adult Orthoptera individuals 'flushed' in a 0.5-m strip in front of the observer were counted (Isern-Vallverdu *et al.* 1993). One observer conducted all of the Orthoptera surveys to minimise any recording error. Each transect was walked once in June, July, August and September in both years of the study. All transect surveys were undertaken under similar weather conditions (sunny, temperature >17˚C). Further details of transect length and number of surveys are displayed in Table 1.

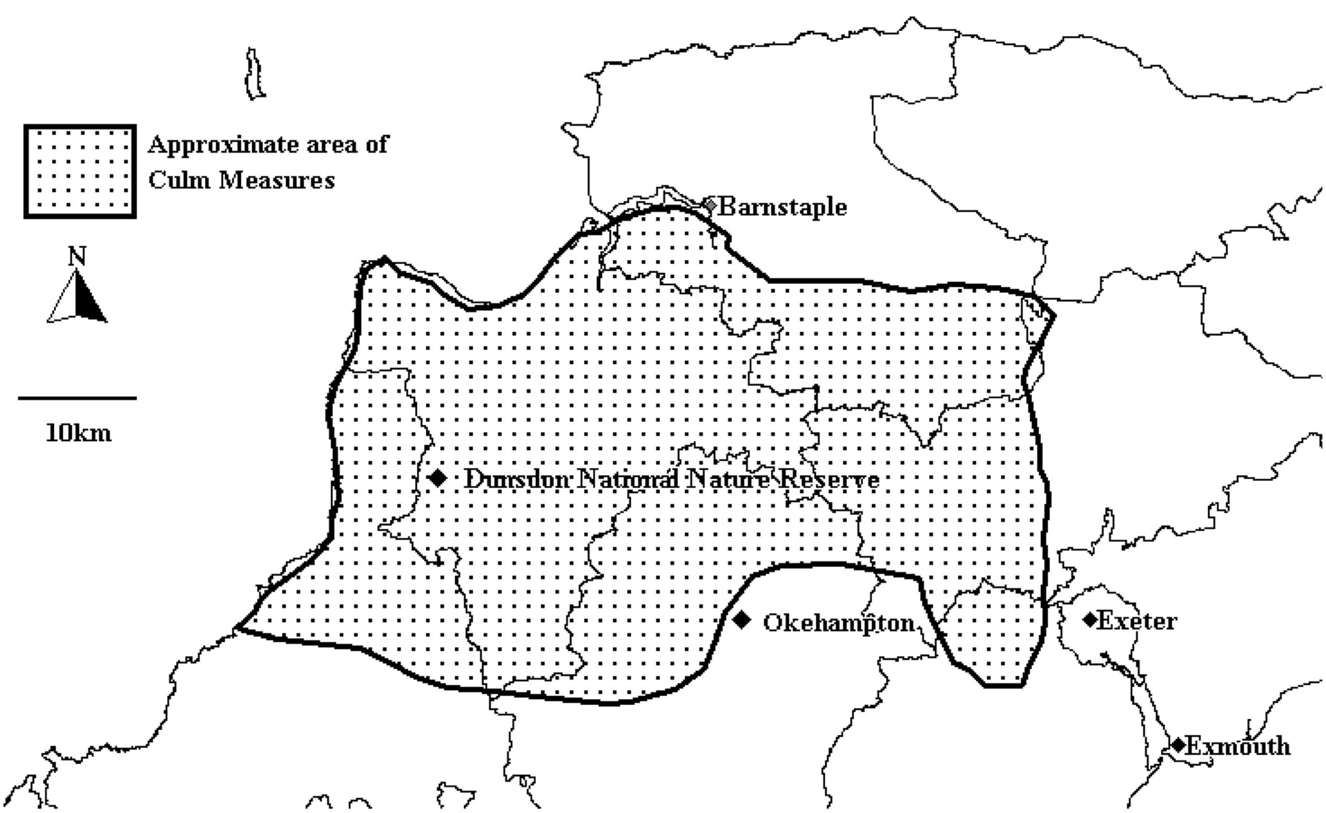

Fig. 1. Location of the Culm Measures and Dunsdon National Nature Reserve (NNR) in northwest Devon, UK.

Table 1. Sampling effort in improved and unimproved pasture for 2002 and 2003 combined.

	Improvement status	
Sampling effort	Improved	Unimproved
Orthoptera surveys		
Transect sections	8	8
Total transect length (m)	400	240
Survey walks	8	8
Habitat variables:		
Drop disc readings	384	384
HGD samples	60	60
Ceptometer readings	80	80
Random quadrats	96	96

HGD = herbage gripping device

Sampling techniques for habitat variables.—Vegetation height was recorded (in mm) using a drop disc method (Smith *et al*. 1993, Stewart *et al*. 2001). The disc weighed 200 g and had a diameter of 300 mm. Vegetation samples were obtained using a herbage gripping device (HGD), a plier-like instrument with extended jaws and parallel gripping surfaces, constructed according to Barthram *et al*. (2000). The gripping surfaces were 9 cm long, 1 cm deep, lined with rubber and opened to approximately 2 cm. The HGD gripped an area of vegetation of approximately 10 cm^2. The device was inserted into the sward and the gripped sample cut away at ground level. Each sample was transported back to the laboratory in paper bags. The samples were dried at 80^0C for 48 h and the dry weight calculated as a measure of herbage biomass. Light penetration (% of incident radiation reaching the ground), to the soil surface and at 1 m above ground in each sward, was measured using a Sunfleck Ceptometer (Decagon Devices Ltd., Pullman, WA, USA).

Botanical composition of the different swards was recorded once per month in June, July, August and September 2002 and 2003 by estimating the percentage cover of vegetation in randomly located 1-m^2 quadrats (Kent & Coker 1992). Additionally, the percentage cover of bare earth and dead leaf litter were recorded. All percentage cover values obtained in the field were converted to the Braun Blanquet cover scale (Duffey *et al*. 1974). Visual estimates of percentage cover were conducted by only one observer, therefore minimising the error associated with this type of subjective vegetation surveying. Further details of the number of samples collected for each habitat variable are displayed in Table 1.

The effect of grassland burning

Study site.—The aim of this small-scale trial was to ascertain the effect of grassland burning on Orthoptera populations and the habitat. The experiment was conducted in 4 pastures, 2 of which were burnt in February 2003. The other 2 pastures were unburnt control plots.

Sampling of Orthoptera populations.—One transect with 4 sections of equal length was established in each pasture. The total length of transect in the burnt and unburnt pastures was 240 and 400 m respectively, with a longer transect necessary in the unburnt pastures due to the larger sampling area. Orthoptera populations of each pasture were monitored using the standard 'flushing' method outlined in Isern-Vallverdu *et al*. (1993). A transect walk was conducted in June, July, August and September of 2003 (post-burn) in the 4 pastures.

Sampling of habitat variables.—Thirty-two random, height measurements (taken using the drop-disc method, Stewart *et al*. 2001) and 5 herbage samples (taken using HGD, Barthram *et al*. 2000) were obtained in each pasture in June, July, August and September 2003. Ten light measurements were recorded in each pasture in June, July, August and September, using the ceptometer method previously described. Percentage cover data for plant species, bare earth and leaf litter were recorded from 8 randomly placed 1-m^2 quadrats (Kent & Coker 1992) in each pasture in June, July, August and September; each cover value was converted to the Braun Blanquet cover scale.

Statistical analysis.—The authors calculated the total orthopteran density per m^2 in both experiments, to determine the effects of management on abundance. The total density for each survey was calculated by dividing the total number of individuals by the total area searched (*e.g.*, for a 200 × 0.5-m transect, the area searched is 100 m on each occasion). Due to the generally low densities of Orthoptera recorded (< 0.50 individuals per m^2), the authors were only able to statistically analyse the total density of Orthoptera for all species combined, not that of individual species in different treatments.

Counts of Orthoptera in tall grassland can be very variable and many zero counts are often recorded, which influences the strategies appropriate for data analysis (Gardiner *et al*. 2005). In swards of variable structure it is safer to use distribution-free nonparametric statistics to avoid any misinterpretation of inferences drawn after analysis (Gardiner *et al*. 2005). Due to the extremely heterogeneous vegetation structure of the pastures, the authors decided to use nonparametric statistics.

To examine whether historical management of the pastures affected total Orthoptera density in improved and unimproved pasture, a Mann-Whitney *U* test was applied (Heath 1995). The test was calculated using the total density (of all species combined) of Orthoptera in each replicate (data for both 2002 and 2003 were pooled) for both improved and unimproved pasture. The effect of burning on Orthoptera density was also examined using the Mann Whitney *U* test, with the authors comparing total Orthoptera density in each replicate for both burnt and unburnt treatments (Heath 1995).

Due to the variability of measurements in each pasture type, the authors also felt it safer to use nonparametric statistics to analyse habitat characteristics. Therefore the Mann-Whitney *U* test was applied to sward height, herbage biomass per m^2 and light penetration to soil surface (non-normality in the ceptometer data was corrected by transformation of percentage values to arcsin before analysis), for each replicate in improved and unimproved pasture and also for burnt and unburnt grassland.

Sward height and Orthoptera density for individual transect sections in both improved and unimproved grassland were compared using Spearman's Rank Correlation (Heath 1995). Due to the low number of replicates for the improvement and burning experiments, the authors felt it reasonable for statistical significance to be accepted at $P<0.10$. Unless otherwise stated no transformation of data was conducted. All statistical analyses were performed using SPSS Version 12 (SPSS 2003).

Table 2. Habitat variables recorded from improved and unimproved pastures; ranges (max. less min.) in parens, except*.

	Improvement status	
Habitat variable	Improved	Unimproved
Herbage height/biomass		
Median sward height (mm)	200 (416)	186 (308)
Median herbage biomass /m² (g)	366 (902)	513 (462)
Microclimate		
Mean % light penetration	31 (42)	27 (45)
Botanical composition		
Median no. plant spp. /m² *(min. , max.)	6 (4, 9)	6 (3,12)
Median Braun Blanquet value:		
Erica tetralix	2	+
Lotus uglinosus	+	2
Molinia caerulea	4	4
Succisa pratensis	1	+
Structural features		
Median Braun Blanquet value:		
Bare earth	Nr	+
Litter	1	1

Braun Blanquet cover scale: + = < 1%, 1 = 1-5%, 2 = 6-25%, 3 = 26-50%, 4 = 51-75%, 5 = 76-100%; Nr = Presence not recorded in survey.

Results

The effect of agricultural improvement.—The ground coverage of *M. caerulea* was very high (51 to 75% ground cover) in the pastures improved in 1840 and the unimproved pastures; consequently very few other herbaceous plants were recorded. Mean sward height was >180 mm in improved and unimproved pasture types (Table 2). Tall vegetation (sward height >250 mm) was recorded in unimproved and improved pasture; however this was distributed heterogeneously. As a result of tall and often dense vegetation (biomass >350 g DM per m²), little light reached the soil surface in both pasture types (<32% light penetration). However, herbage height (Mann-Whitney *U* value: 1) biomass (*U* = 2) and light penetration (*U* = 1), did not differ significantly (p >0.10) between improved and unimproved pasture.

Both pasture types had the same number of plant species per m² (6 species, Table 2), although some areas of the unimproved fields were relatively species rich (>10 plant species per m²). Bare earth was only recorded in the unimproved pasture in very limited quantity (<1% cover). Small quantities (1 to 5% ground cover) of dead-leaf litter were recorded in the improved and unimproved pastures.

Four species of Orthoptera were recorded in this study (Table 3). The most frequently recorded species was the meadow grasshopper, *Chorthippus parallelus*, forming 93% of the total sightings. Common green grasshopper, *Omocestus viridulus* (total sightings: 21) and the 2 groundhopper species (slender groundhopper, *Tetrix subulata* and common groundhopper, *Tetrix undulata*, combined sightings: 6) were much less frequently observed.

Densities of Orthoptera in improved and unimproved pasture did not differ significantly (Mann-Whitney *U* test value: 0, p >0.10). Population densities were however, very variable, particularly in the unimproved pastures. For example, in an area of particularly short pasture (sward height <150 mm), on very acidic soil (pH < 4), with a high abundance of cross-leaved heath *Erica tetralix* (>50% ground coverage), densities of >1 individual per m² were recorded (Fig. 2). However, in taller swards (>200 mm), densities were always lower than 0.2 individuals per m², leading to a highly significant negative relationship between sward height and Orthoptera population density in unimproved grassland (r_s = -0.84, p <0.01). A similar significant relationship was not detected for improved pasture (r_s = -0.61, p >0.10).

Table 3. Total number of Orthoptera (adults and nymphs) in improved and unimproved pastures (data for 2002 and 2003 combined; no of nymphs recorded in parens). Orthoptera density is total number of individuals recorded/total transect area searched [(transect length × no of surveys) × 0.5]; density range is difference between max. and min. densities of Orthoptera per survey.

	Improvement status		
Species	Improved	Unimproved	Total no.
Acrididae			
Chorthippus parallelus	116 (39)	225 (58)	341 (97)
Omocestus viridulus	19	2	21
Tetrigidae			
Tetrix undulata	0	1	1
Tetrix subulata	2	3	5
Total no. of individuals	137 (39)	231 (58)	368 (97)
Orthoptera density /m²	0.08	0.24	
Density range /m²	0.52	1.60	

The effect of burning.—Sward height and herbage biomass were lower on the burnt pastures when compared with the unburnt control areas in 2003 (Table 4), although these differences were not significant (Mann-Whitney *U* test value for both sward height and biomass: 0, p >0.10). Light penetration to the soil surface was higher on burnt pastures when compared to the unburnt replicates in the post-burn season (30 *vs* 13 % respectively) although this difference was not

Table 4. Habitat variables recorded from burnt and unburnt pasture in 2003, post-burn season; ranges (max. less min.) in parens, except *.

	Treatment	
Habitat variable	Burnt	Unburnt
Herbage height/biomass		
Median sward height (mm)	139 (249)	277 (565)
Median herbage biomass /m² (g)	309 (418)	726 (1206)
Microclimate		
Median % light penetration	30 (45)	13 (26)
Botanical composition		
Median no. plant spp. /m² *(min. , max.)	6 (4, 9)	6 (4, 9)
Median Braun Blanquet value:		
Erica tetralix	2	+
Molinia caerulea	4	5
Potentilla erecta	1	1
Succisa pratensis	2	1
Structural features		
Median Braun Blanquet value:		
Bare earth	Nr	Nr
Litter	+	1

Braun Blanquet cover scale: + = <1% cover, 1 = 1-5%, 2 = 6-25%, 3 = 26-50%, 4 = 51-75%, 5 = 76-100%; Nr = Presence not recorded in survey.

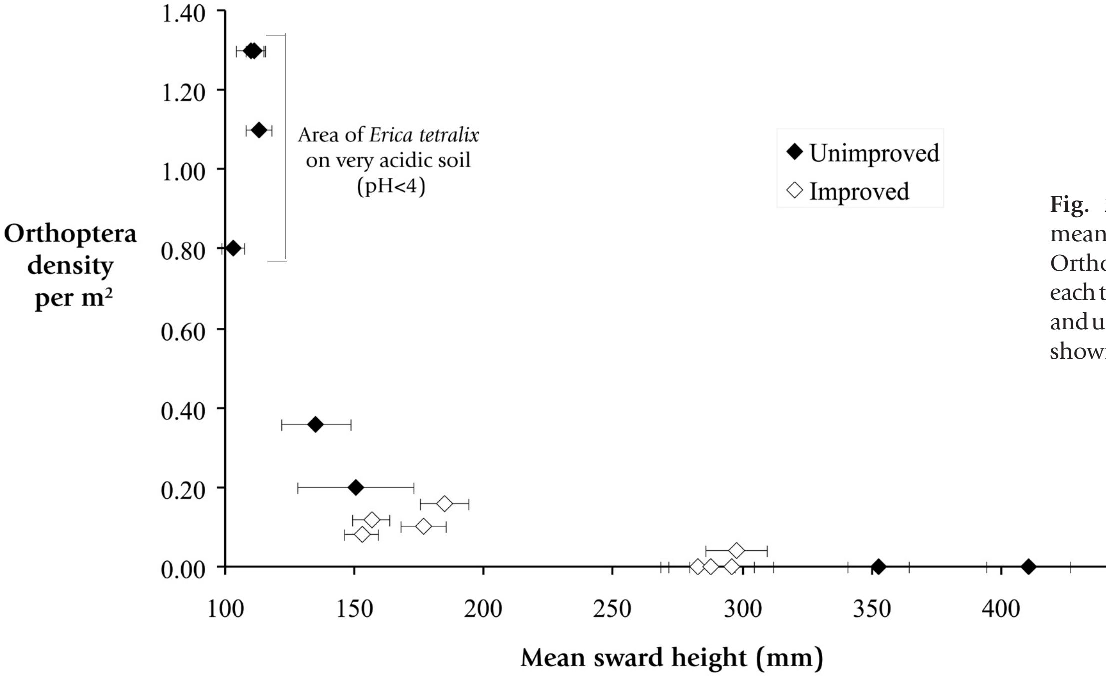

Fig. 2. Relationship between mean sward height and median Orthoptera density per m² in each transect section in improved and unimproved pasture (SE bars shown).

significant (Mann-Whitney *U* value: 0, p >0.10). Although there was no difference between the number of plant species per m² in the burnt and unburnt pastures, the ground coverage of both *E. tetralix* and devil's-bit scabious, *Succisa pratensis*, was greater on the burnt areas. Conversely, the ground coverage of *M. caerulea* and of leaf litter were lower in the burnt pastures.

In 2003 (post-burn), population densities of Orthoptera were higher on the burnt pastures when compared with the unburnt control grassland (0.29 *vs* 0.01 individuals per m² respectively), although this difference was not significant (Mann-Whitney *U* value: 0, p >0.10). However, only 2 species were recorded on the burnt pasture in 2003, *C. parallelus* and *O. viridulus* (Table 5). Four species were observed in the unburnt control grassland: *C. parallelus*, *O. viridulus*, *T. subulata* and *T. undulata*.

Discussion

The total number of species of Orthoptera recorded in Culm grasslands is relatively low (4 species, Table 3) and compares poorly with the best sites in the UK, such as the Dorset Heathlands (24 species), New Forest (24 species) and the Purbeck Hills (21 species) (Marshall & Haes 1988). Other species of Orthoptera occur in north Devon but have not been associated with Culm grasslands, including the field grasshopper, *Chorthippus brunneus*, and mottled grasshopper, *Myrmeleotettix maculatus*, (Marshall & Haes 1988, Haes & Harding 1997). These species favor short, sparse vegetation with patches of exposed soil (Haes & Harding 1997), suggesting a reason for the absence of both species from the tall and dense *Molinia*-dominated vegetation (exposed bare earth <1%), where it may be difficult for individuals (particularly of *M. maculatus*) to raise their body temperature due to the low sward temperatures (Willott 1997).

The 2 grasshopper species recorded, *C. parallelus* and *O. viridulus*, are characteristic of moist grassland (Brown 1983), with the latter species being considered as an indicator of ancient unimproved grassland (Marshall & Haes 1988). However, in this study, *O. viridulus* was observed in pastures which had been improved through drainage and cropping in the 1800s.

Culm grasslands are not an optimal habitat for the most numerous orthopteran, *C. parallelus*, due to the tall sward height (generally >180 mm, Table 2) and low light penetration to the soil surface (<32%, Table 2). Vegetation structure may influence egg development. Tall vegetation could lead to lower maximum temperatures and poorer light penetration to the soil surface. This might consequently delay hatching of eggs laid in the soil, resulting in a loss of some mesophilous grasshopper species such as *C. brunneus* (van Wingerden *et al.* 1991).

Tall grasslands, such as those investigated in this study, may be described as 'cold', whilst those with shorter, sparse vegetation are 'warm' (van Wingerden *et al.* 1991). *O. viridulus* may be able to exist in 'cold' grasslands throughout the UK, due to its ability to raise its body temperature in such environments and inability to effectively reduce it in 'warm' grasslands, where it may overheat at high temperatures (Willott 1997).

C. parallelus is most abundant in short swards, approximately 100 to 200 mm in height (Gardiner *et al.* 2002), which would seem to indicate that the 150-mm 'optimum' sward height suggested by Wolton (1991) may lead to higher numbers of this species than 'rank' unmanaged swards >200 mm. However, due to the low abundance of Orthoptera species it is very difficult to form any conclusions about the management that may be suitable for other species.

The authors suggest that improvement of a sward through ploughing may destroy eggs of species such as *C. parallelus*, which are laid in the soil (Choudhuri 1958), and those of *O. viridulus* which are deposited in vegetation (Brown 1983), causing a low abundance of grasshoppers in regularly ploughed fields (Gardiner *et al.* 2002). Lockwood (2004) describes how ploughing can push locust eggs deep into the soil causing hatching failure, whereas irrigation where eggs are laid, may lead to high mortality. Therefore, it is likely that improvement of farmland at Dunsdon through ploughing and drainage in the 1800s, led to the eradication of grasshopper populations in these fields, although the authors acknowledge that they have no historical evidence of this.

Once cropping of the pastures finished in the late 1800s, natural reversion back to grassland occurred. Before 1900, Culm grassland

Table 5. Total number of Orthoptera recorded from burnt and unburnt grassland in 2003; proportion of total numbers in each treatment in parens. Orthoptera density is total number of individuals recorded/total transect area searched [(transect length × no of surveys) × 0.5]; density range is difference between max. and min. densities of Orthoptera per survey.

	Treatment	
Species	Burnt	Unburnt
Acrididae		
Chorthippus parallelus	139 (0.99)	7 (0.64)
Omocestus viridulus	1 (0.01)	2 (0.18)
Tetrigidae		
Tetrix undulata	0	1 (0.09)
Tetrix subulata	0	1 (0.09)
Total no. of individuals	140	11
Orthoptera density / m^2	0.29	0.01
Density range / m^2	2.00	0.68

sites such as Dunsdon NNR were situated within a large network of unimproved habitat, with suitable patches of unploughed pasture nearby (Wolton 1991). Therefore, relatively mobile grasshopper species such as *C. parallelus*, which display highly directional resource-led movements in grazed habitats (Gardiner & Hill 2004), may easily have colonised the reverted pastures from surrounding pastureland in the 127 years since cropping finished and this survey commenced. This recolonisation of reverted grassland may account for the comparable densities of Orthoptera (of which *C. parallelus* is the dominant species, Table 3) between improved and unimproved pasture in this study. Further research is needed into the effects of ploughing on Orthoptera populations and the speed of recolonisation of reverted habitats, because there are so little accurate data on this subject.

Extant unimproved sites can support relatively high numbers of Orthoptera (>1 individual per m^2, Fig. 2), although populations appear to be extremely localised. This is perhaps in relation to the tussocky growth form of *M. caerulea*, which creates substantial heterogeneity in sward height and temperature (Griffith 1951, Rodwell *et al.* 1991). Orthoptera were most numerous in the shorter swards (<150 mm), those that closely resembled wet heathland with low pH (<4) and an abundance of *E. tetralix* (Fig. 2). Therefore, where *Molinia* growth is restricted on very acidic soils, there may be swards of high suitability for Orthoptera, perhaps due to the 'warm' microclimate which leads to increased postdiapause development (PDD) in the egg stage (van Wingerden *et al.* 1991, van Wingerden *et al.* 1992).

Grassland burning in this study led to increased Orthoptera abundance (density 29× greater on burnt plots than on unburnt replicates) in the post-burn year, as in the studies of Samways (1994) and Bieringer (2002). It is likely that mesophilous species such as *C. parallelus*, which overwinter as egg pods in the soil, may escape the main destructive impact of winter burning. The reduced sward height/biomass and increased light penetration on burnt swards in April/May could lead to enhanced PDD and basking opportunities for hatched nymphs.

Our results must be viewed with some caution due to the small-scale of our study and its low replication (only 2 replicates for each treatment due to practical difficulties with selection of suitable plots). This certainly hampered statistical analysis, particularly in the burning experiment where there was no significance between treatments despite the substantially higher numbers on the burnt plots (Table 5). The high heterogeneity of vegetation structure also led to much variation in Orthoptera densities and sward characteristics, further complicating analysis.

In conclusion, it is important that future studies have a higher number of replicates (at least 4) to improve the validity of the data and increase chances of finding statistical significance between treatments. However, the present study should provide base-line information for more extensive research on appropriate management techniques. The impact of different grazing intensities on insect populations, perhaps using Orthoptera as a group of indicator species, is one possible area of investigation.

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