Grasshopper strips prove effective in enhancing grasshopper abundance in Rivenhall Churchyard, Essex, England

Tim Gardiner[1*], Michelle Gardiner[1] & Nigel Cooper[2]
[1]*2 Beech Road, Rivenhall, Witham, Essex CM8 3PF, UK*
[2]*Anglia Ruskin University, East Road, Cambridge CB1 1PT, UK*

*Corresponding author e-mail: timgardiner134@btinternet.com

SUMMARY

Grasshopper strips (alternate, 1-m wide strips of uncut and cut grassland) are a novel conservation feature in a rural churchyard in the village of Rivenhall (Essex), southeast England. The effectiveness of these strips in enhancing the abundance of grasshoppers (Acrididae) was investigated during the summer of 2010 using sweep-net surveys. Two grasshopper species were recorded. The meadow grasshopper *Chorthippus parallelus* was significantly more abundant in the cut grasshopper strips than in nearby short grassland (control) plots regularly mown throughout the summer. The field grasshopper *Chorthippus brunneus* was contrastingly more abundant in the uncut grasshopper strips than in the controls. The grasshopper strips appear to provide a mosaic of short and tall grassland in close proximity which is required for nymphs and adults of both *C. parallelus* and *C. brunneus*.

BACKGROUND

There are over 20,000 churchyards in England and Wales, and they can be havens for wildlife as well as burial grounds (Greenoak 1993). Churchyards provide wildlife habitats both in built-up and rural areas, assuming increasing conservation importance as urban areas expand and 'greenspace' is lost, and as agricultural practices intensify (Rackham 1986). Grasslands in churchyards are predominantly undisturbed, having received no agricultural intervention such as ploughing, and are not subject to application of inorganic fertilisers or herbicides. The long continuity of these grasslands (often hundreds of years) has led to the development of species-rich herbaceous plant communities of high conservation value (Cooper 1995) with associated grassland invertebrates. Many churchyards are now managed to encourage wildlife (Cooper 2001), a common feature being a 'conservation' area, often composed of grassland left uncut throughout the summer aiming to benefit floristic diversity and insects, in particular.

With regards insects, churchyard grassland conservation areas have been shown to benefit grasshoppers (and also butterflies and dragonflies) in Essex, southeast England (Gardiner & Pye 2001). For example, in All Saints Churchyard in the village of Writtle, five species of Orthoptera (grasshoppers and bush-crickets) were recorded in a conservation area managed by a traditional hay-cut in August, but were absent from adjacent short grassland sward mown regularly (every 2-3 weeks) throughout the summer. In some Essex churchyards, range-expanding species such as long-winged conehead *Conocephalus discolor* and Roesel's bush-cricket *Metrioptera roeselii* have been recorded in tall grass conservation areas in recent years, for example at Norton Mandeville Churchyard (Gardiner 2009b). A study in Colchester Cemetery found that two *Chorthippus* grasshoppers (*C. brunneus* and *C. parallelus*, both widespread in the UK) were in highest abundance in the tall grassland of uncut wildflower meadows compared to adjacent short swards mown regularly throughout the summer (Tarpey 1996). Although the biodiversity importance of tall grass areas is recognised in a recent management plan for this cemetery, it is acknowledged that public perception of the untidy appearance of these swards has meant that some tall grassland

areas have been returned to intensive, regular summer mowing (Colchester Borough Council 2010). Concern was expressed about the lack of tall grassland in the Cemetery during a recent survey by members of the Colchester Natural History Society; they suggest that the short grassland allows no opportunity for colonisation by grasshoppers (Colchester Borough Council 2010). Apart from Tarpey's study of Colchester Cemetery, there have been no quantitative investigations of the effectiveness of conservation interventions in churchyards aimed at enhancing orthopteran abundance.

In this present study, 'grasshopper strips' were established in the churchyard of St. Mary and All Saints in the village of Rivenhall (Essex). This novel but simple management approach comprised allowing strips of tall grass to establish during the summer months, alternated with short (more regularly mown) grassland. This was aimed at providing a variety of sward heights deemed required by two grasshopper species (Acrididae) present in the area to complete their life cycles. This paper describes surveys conducted to quantify the effectiveness of the grasshopper strips in enhancing the abundance of grasshoppers.

ACTION

Study site: St. Mary and All Saints Church (Ordnance Survey grid reference: TL 827178) is situated in the rural parish of Rivenhall, Essex, southeast England. The original Saxon church was built over a Roman villa. The current building dates from 1838-39. The churchyard is approximately 0.8 ha in area, lying on a chalky boulder clay soil. It is bordered on its south side by a school, on its eastern and northern edges by sheep grazed pasture, and by a road and arable field to the west. The churchyard grassland has plant species characteristic of unimproved grassland of the region, including burnet saxifrage *Pimpinella saxifraga*, common knapweed *Centaurea nigra*, cowslip *Primula veris*, field scabious *Knautia arvensis* and lady's bedstraw *Galium verum*. It also supports yellow meadow ants *Lasius flavus* (a widespread species of well-drained grasslands in the UK) and their ant-hills, further indicating the historically unimproved nature of the grassland. Most of the grassland is regularly mown throughout the growing season (every 2-3 weeks from April-October), with small patches (amounting to about 10% of the churchyard) left uncut through the summer as conservation areas. There are scattered trees providing some shade.

Grasshopper strips: Alternating strips of cut and uncut grassland (i.e. grasshopper strips) orientated approximately east-west, were established in 2002 on the north side of the church (Cooper 2002). They receive some shade from the Church tower after 12:00 h. There are three uncut strips (plots B, D, F; Fig. 1) each 12 m long x 1 m wide (uncut throughout the summer, June-August) within which grass height ranges from approximately 10-40 cm throughout June-August. The predominant grass is yellow oat-grass *Trisetum flavescens*, with occasional herbs such as *C. nigra*, *G. verum* and ox-eye daisy *Leucanthemum vulgare*. The cut strips (also 12 x 1 m) (A, C, E; Fig. 1) are mown every 2-3 weeks from June-August, in keeping with the general regular mowing pattern of most of the churchyard. The grass height in the cut strips is generally less than 10 cm, but with plant species similar to the uncut plots. The uncut and cut plots represent a mosaic of vegetation heights in a much larger area of short mown grassland. Ant hills (of *L. flavus*) are present near uncut strips. Given prior knowledge of the habitat requirements of the target grasshopper species, it was also hoped that this style of management would look 'neat and tidy' thus indicating deliberate management, therefore making it more acceptable to the general public, as opposed to a large homogenous area of grassland left uncut.

To facilitate comparison with the grasshopper strips, six control plots (each 12 x 1 m) were established in grassland that was regularly mown (every 2-3 weeks) throughout the summer (June-August). This cutting regime represents the traditional amenity management of the churchyard. The control plots were situated to the east of the grasshopper strips, separated from them by a 5 m buffer zone (regularly mown grass) to reduce edge effects, such that they were paired with the grasshopper strip plots. The grass height in all control plots was maintained at less than 10 cm. Plant species were similar to those in the grasshopper strips; no ant hills were present.

Mown controls (all cut)

←1 m→ ↑ 12 m A ↓	B	C	D	E	F

←N

Buffer zone of cut grassland

Grasshopper strips

←1 m→ ↑ 12 m A ↓ (cut)	B (uncut)	C (cut)	D (uncut)	E (cut)	F (uncut)

Figure 1. Layout of the six control (regularly mown) plots and their adjacent paired uncut (B, D and F) and cut (A, C, E) plots (grasshopper strips), separated by a 5-m wide mown grass buffer zone. Each of the 12 plots was 12 m long by 1 m wide.

Grasshopper sweep-net surveys: Sweep-net sampling was used to assess abundance of grasshopper species in the grasshopper strips and controls. Sweep-netting is rapid and the most frequently used sampling method to assess relative abundance and species composition of grassland orthopteran assemblages (Gardiner *et al*. 2005). A standard procedure was used, sweeping the vegetation once back and forth in an 180^{o} arc in front of the observer (defined as 1 sweep). The net was passed through the vegetation at approximately 5 cm above the soil surface at a fast speed, and with a short net arc length (approx. 1 m) to maximise grasshopper catch rate (O' Neill *et al*. 2002). Ten sweeps were undertaken at 1-m intervals in each plot during each survey (a total of 120 sweeps per survey).

Adult grasshoppers caught in every sweep were identified to species and released into the vegetation behind the next sweep to avoid recapture (hence double-counting). However, nymphs (especially smaller instars) are difficult to assign to species in the field (e.g. Richards & Waloff 1954). In preliminary surveys of the experimental areas (2008 and 2009) only two *Chorthippus* species were identified. Likewise, the same two species were the only orthopterans recorded during this study. Therefore nymphs could be fairly confidently assumed to belong to this genus and any nymphal individuals caught were recorded as *Chorthippus* spp. nymphs.

Surveys were conducted at weekly intervals from 25 June to 5 August 2010 (seven surveys in total) in the late afternoon (after 16:00 h) as Marshall & Haes (1988) advise that recording grasshoppers at this time is easiest as they are less active and therefore less likely to escape capture. Weather conditions during surveys were warm (air temperature > 17^{o}C) and sunny (< 50% cloud cover).

Grasshopper quadrat density estimate: On 5 August (peak grasshopper season), a total of five randomly located quadrats (positions determined using a random number table) were flushed for grasshoppers (total area searched 20 m^{2}) in the grasshopper strips. Quadrats were used to measure density to ensure that the data were directly comparable with estimates from other sites in Essex where this method has also been utilised (e.g. Gardiner *et al*. 2002). The area of each quadrat was equally divided between cut and uncut grasshopper strips. Each corner of a 2 × 2 m quadrat was marked with a pole (taking care not to disturb grasshoppers within). The insects were then flushed by brushing the

vegetation with a 1 m long stick. Flushing proceeded from one edge of the quadrat to the other, sweeping vegetation in an 180˚ arc. Grasshoppers within the quadrat at the start of the sweep were recorded (those leaping in from outside discounted). It took approximately 30 seconds to sample each quadrat. No attempt was made to identify grasshoppers to species due to the high level of activity and frequent escape movements after flushing. As a benchmark, an exceptionally favourable site for grasshoppers in Essex has a density of more than 3 adults per m^2 measured using the quadrat technique (Gardiner *et al*. 2002). It is against this that the grasshopper strips were compared as a measure of their effectiveness.

Analysis: The number of nymphal and adult grasshoppers collected by sweep-netting was summed for each of the control (A-F) and each grasshopper strip plots. Numbers present in cut and uncut grasshopper strip plots were also analysed separately. Adult grasshoppers were subdivided into. The data for *Chorthippus* spp. nymphs and *C. brunneus* and *C. parallelus* adults for each plot was square root transformed to correct for non-normality (Gardiner *et al*. 2005). The transformed abundances were compared using a paired samples Student's t-test between cut grasshopper strips and their paired mown control plots (A vs. A, C vs. C and E vs. E) to determine if the abundance of nymphs and adults was significantly higher on the cut grasshopper strips. Similarly, abundances were compared between uncut grasshopper strips and their paired mown control plots (B vs. B, D vs. D and F vs. F).

As a comparison of the abundance estimates obtained using sweep-net surveying and quadrats, the estimated density per $1m^2$ of *Chorthippus* adults was compared for both techniques for the grasshopper strips (combined) on 5 August. During sweep-net surveys, it was assumed that an area of ground 1 m (sweep-net arc length) x 0.5 m was swept. Therefore for each sweep an area of 0.5 m^2 was sampled.

CONSEQUENCES

Abundance from sweep-net surveys: In total, 312 grasshoppers (all life stages and species combined) were collected in sweep-net samples within the grasshopper strips (cut and uncut), compared to 77 in the mown control plots (Table 1). Two species of orthopteran were recorded, *C. brunneus* and *C. parallelus*. Statistically significantly higher numbers of *C. parallelus* adults were present in the cut grasshopper strips than in the controls ($t = 4.53$, $P<0.05$; Fig. 2). The abundance of *C. brunneus* adults was contrastingly higher in the uncut grasshopper strips than in the controls ($t = 5.23$, $P<0.05$). However, despite the much higher abundance of *C. parallelus* in the uncut and *C. brunneus* adults in the cut grasshopper strips, there were no statistically significant differences detected between cut and uncut plots. There was no significant difference detected in the abundance of *Chorthippus* spp. nymphs in (either cut or uncut) grasshopper strip plots and their paired control plots.

Quadrat density estimates: On 5 August, 61 adult grasshoppers (both *Chorthippus* species combined) were counted in the five quadrats (range 10-14 individuals). This equates to a density of 3.1 adults per m^2 i.e. an exceptionally high density of grasshoppers in an Essex county context.

Comparison of density estimates: The density estimate of adult grasshoppers (both *Chorthippus* species combined) derived from the quadrat surveys (3.1 adults/m^2) was over three times greater than that obtained using sweep-netting (1.0/m^2) on 5 August.

Table 1. Numbers of adult grasshoppers and nymphs in the grasshopper strips (data for cut and uncut plots combined) and mown control plots, recorded during sweep-net surveys, 25 June to 5 August 2010.

Species/life stage	Grasshopper strips	Mown controls
Chorthippus spp. nymphs	107	44
C. brunneus adults	104	26
C. parallelus adults	101	7
Total	**312**	**77**

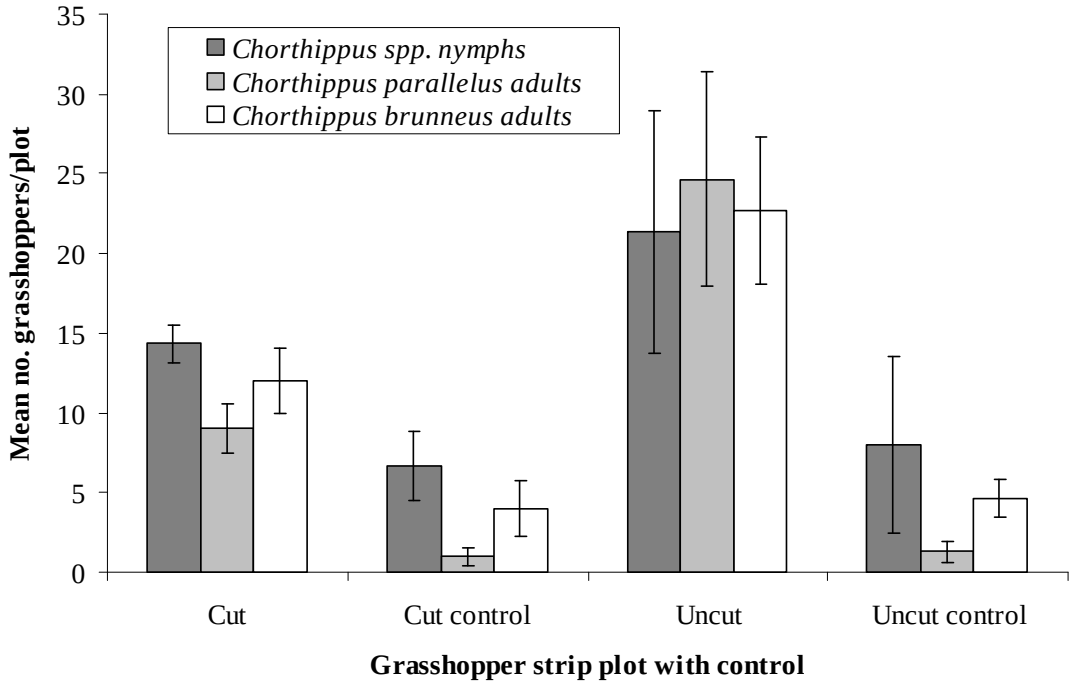

Figure 2. Mean number of *Chorthippus* spp. nymphs and *C. brunneus* and *C. parallelus* adults in the cut and uncut grasshopper strips and their paired mown control plots (standard error bars shown).

Discussion: The grasshopper strips enhanced habitat for the two acridids in the churchyard grassland (as indicated by their increased abundance). *C. brunneus* adults favoured strips of uncut grass within the grasshopper strips whereas *C. parallelus* were more abundant in the cut grasshopper strips, as compared to the regularly mown controls. Both species prefer a heterogeneous sward of around 10-20 cm height (Gardiner *et al*. 2002) and the combination of cut and uncut strips appeared to provide the mosaic of short and tall vegetation that these *Chorthippus* grasshoppers require (Gardiner 2009a). Movement of grasshoppers away from ovipositing sites (areas dominated by short grass and bare earth), to taller vegetation providing food and shelter has been observed (Richards & Waloff 1954). Early instar nymphs may be found in spring in the proximity of bare earth and short grassland (that provide a warm micro-climate upon emergence) in which egg-laying occurred. As they mature they disperse into taller grass that often has a higher nitrogen content than shorter vegetation (Grayson & Hassall 1985), hence grasshopper growth may be enhanced (Port & Thompson 1980). Later in the year, dispersal may also occur due to the sometimes excessively hot microclimate (temperatures > 44^{o}C) of mown swards (Gardiner & Hassall 2009, Gardiner 2009a) to taller vegetation in search of shade. Movement of *C. parallelus* adults from short to tall grassland habitats have been noted in a study in Essex (Gardiner & Hill 2004).

At the end of the summer, adult *C. parallelus* and *C. brunneus* visit areas of short vegetation and bare earth in which to oviposit. It is likely that the sparsely vegetated *L. flavus* ant hills around the grasshopper strips may be preferred oviposition sites in the churchyard (although no females were observed actually ovipositing on them). The short grassland may also provide a suitable egg-laying environment where mowing has exposed patches of soil (Brown 1983). Therefore, situating grasshopper strips near to such areas may be beneficial.

Grasshoppers are known to suffer mortality during mechanised summer mowing of hay meadows (Gardiner & Hill 2006b). It is thought that larger mature nymphs and adults, and their location in the lower layers of the sward (< 20 cm; Gardiner & Hill 2005) may

render them susceptible to death or damage through contact with rotary cutting blades. The Rivenhall Churchyard is cut using a rotary mower thus grasshoppers are probably killed during mowing, however, those jumping clear may find refuge in the uncut strips present until late summer.

The choice of sampling method appeared important in obtaining a grasshopper density estimate. The August 2010 quadrat survey revealed a higher density of adult grasshoppers in comparison to sweep-netting. The surveyor noted that many grasshoppers escaped capture during sweep-netting despite a rapid sweep speed. If density estimates are required in similar habitats, then we suggest that quadrat sampling is used (Gardiner *et al*. 2002; Gardiner & Hill 2006a). The quadrat survey revealed a high density (3.1 adults/m^2) of grasshoppers, placing the grasshopper strips in the churchyard amongst the few sites in Essex where grasshopper abundance is so great (Gardiner *et al*. 2002). This is likely to be due to a combination of the management (providing short and tall grassland in close proximity) and the long continuity of the ancient unimproved sward.

As well as providing suitable grasshopper habitat, the use of grasshopper strips may further lend itself to insect conservation in churchyards and cemeteries where the presence of large areas of tall grassland may otherwise be seen as untidy and unsightly by members of the public.

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