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Orthoptera of crossfield and headland footpaths in arable farmland

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Abstract

A study was made of Orthoptera assemblages of crossfield and headland (field-edge) public footpaths in the Chelmsford area of Essex, UK, in 2006. Orthoptera populations were monitored using a standardised transect counting procedure in both footpath types to determine whether headland footpaths provided benefits to Orthoptera on intensively managed farmland. Species richness of Orthoptera was significantly higher on headland footpaths (6 species) than on crossfield rights of way (3 species), suggesting that footpaths along the edges of fields may provide refuges in arable farmland. It seems that the absence of regular ploughing on the headland footpaths may be beneficial to mesophilous grasshopper species, the crossfield footpaths constituting too much of an ephemeral habitat (due to annual ploughing and cropping) to support the full range of species. Abundance of all Orthoptera and of individual species was not significantly higher on headland footpaths, although replicates on the sheltered and sunny eastern side of hedgerows had relatively high densities.

Key words

public rights of way, grasshoppers, bushcrickets, grass margin, field edge, hedgerow, ploughing

Introduction

Ecologists have often studied the effects of recreation on plant communities, particularly through trampling associated with walking (Liddle 1997). However, the effect of footpath usage on insects is not well documented and a considerable research deficit exists. Insect orders such as Orthoptera can be good indicators of habitat that is in favorable condition (van Wingerden *et al*. 1992, Wettstein & Schmid 1999, Gardiner *et al*. 2002), for example, grasshoppers in Alpine grasslands were extremely scarce in pastures subjected to intense human trampling (Voisin 1986). Little is known about the Orthoptera assemblages of public footpaths in the UK, particularly those that occur on farmland where grasshoppers (Acrididae) and bushcrickets (Tettigoniidae) are scarce (Gardiner *et al*. 2002, Gardiner & Hill 2003).

The public rights of way (PROW) network in Essex is extensive, with > 6000 km of highway (Essex County Council 2006). As the main land use is agricultural (ECC 1996), most of the public footpaths (access on foot only) are situated on farmland, with footpaths either running along the edge of arable fields (headland footpaths) or across the middle (crossfield footpaths) (Riddall & Trevelyan 2001). It is not known how important each type of footpath is in providing habitat for Orthoptera, particularly for species such as the Field Grasshopper *Chorthippus brunneus*, which prefer grassland with patches of exposed soil (Marshall & Haes 1988), that is, they prefer habitat conditions which may well occur on footpaths that are trampled by walkers (Liddle 1997).

It is the aim of this paper to ascertain whether headland footpaths are beneficial to Orthoptera in arable farmland by describing and discussing the results of a small-scale study that compared Orthoptera abundance and species richness on crossfield and headland footpaths in 2006 in Chelmsford, Essex, UK.

Methods

Study site.—The farmland footpaths in this study were all legal PROW (routes registered on the definitive map of Public Rights of Way) situated on farmland in Boreham, located just outside Chelmsford, Essex, UK. The soil underlying the footpaths is predominantly chalky boulder clay with high water retention in winter and high nutrient levels, a soil type similar to that of nearby Writtle College (Neate 1979). The Writtle area has a temperate climate with an average air temperature of 10°C and total annual rainfall of approximately 550 mm (Writtle College 2003). A high proportion of the arable area of the farmland is cropped with winter cereals (wheat and barley). Field sizes in the area were fairly large, ranging from 2.5 to 33 ha (mean field size = 13 ha) and managed intensively to maximise yield.

The footpaths.—The general characteristics of all the footpaths surveyed are displayed in Table 1. The footpaths comprised two different types: crossfield (across the middle of arable fields) and headland (along field edges).

Crossfield (4 replicates).—The four crossfield footpath replicates (for more details see Table 1) ran directly across the middle of arable fields and as such were ephemeral in nature due to the ploughing and cropping of the fields on a yearly basis. The crops were sown in August/September of 2005 and sprayed with insecticides in September to November 2005 to control aphids and flea beetles. Nitrogen fertiliser (N) was applied to all fields in this study from September 2005-April 2006, in varying amounts due to the nutrient requirements of each field (min/max N input per field: 250-943 kg/ha/y). The Highways Act (1980) requires landowners to reinstate crossfield paths after ploughing (on an annual basis) so that walkers can negotiate their way through the cropped fields. The landowner in this study sprayed each crossfield path to the width of 1.5 m with herbicide (Round-up ®, main ingredient Glyphosate) in March 2006 to kill all crop cover within the path boundary and create a bare-earth track through the fields (Fig. 1). Harvesting of the fields occurred between 13 July and 10 August 2006, after which the fields were ploughed and harrowed.

Table 1. Characteristics of the farmland footpaths.

Footpath type/ replicate no.	Footpath number*	O.S. grid ref**	Transect length (m)	Hedge	Grass margin *** (width in m)	Crop
Crossfield						
1	16	TL738105	486	No	No	Barley
2	17	TL751109	412	No	No	Wheat
3	17	TL754109	232	No	No	Wheat
4	17	TL757110	246	No	No	Wheat
Headland						
1	15	TL740107	162	Yes	Yes (2)	Barley
2	15	TL740105	260	Yes	Yes (2)	Barley
3	15	TL742101	104	Yes	Yes (2)	Wheat
4	15	TL742102	122	Yes	Yes (6)	Wheat
5	15	TL741103	180	Yes	Yes (6)	Wheat
6	21	TL755111	320	Yes	No	Wheat
7	21	TL756108	396	Yes	No	Wheat
8	16	TL742108	478	Yes	Yes (4)	Oil Seed Rape

* footpath numbers refer to the parish of Boreham and an inspection of the definitive map of public rights of way can be made at County Hall, Chelmsford, UK
**Ordinance Survey® grid references based on grid mapping system in the UK
*** grass margins established under the Entry Level Stewardship (ELS) scheme to promote biodiversity on farmland

Fig. 1. Crossfield footpath (note the sporadic patches of vegetation). See also PLATE I.

Headland (8 replicates).—The headland (field-edge) footpaths (Table 1) were managed by the landowner under Essex County Council's Headland Management Scheme (HMS). The HMS was introduced in 2003 to allow landowners and farmers the opportunity to cut field-edge PROW within their own landownership boundaries with financial support from Essex County Council. Landowners are paid to undertake two cuts a year on their headland paths and must reinstate all crossfield paths within their landownership after ploughing has occurred. In this study all headland paths were cut once in May and once in July 2006. The headland footpaths were not ploughed and it is illegal to do so under the Highways Act (1980).

Two sections of headland footpath had no Entry Level Stewardship (ELS) grass margins adjacent (Table 1). These headlands formed part of a farm track (*c.* 3 m wide) that is frequently used by landrovers or tractors (Fig. 2 shows the headland track). Six of the headland footpaths were adjacent to ELS grass margins of varying width (2 to 6 m wide, Table 1). The margins were in addition to each 1.5-m headland (1.5-m wide headland + 2-m ELS margin = strip of 3.5 m next to hedgerow). The ELS is part of the Environmental Stewardship Scheme and is an option open to all farmers in an effort to introduce environmental measures on agricultural land throughout the UK. The margins were sown with a Timothy/Cocksfoot mix in autumn 2005. The main grass species on the headland footpaths were Perennial Ryegrass *Lolium perenne* and Cocksfoot *Dactylis glomerata*.

Table 2. Total number of each Orthoptera species and species richness recorded on crossfield and headland footpaths (median density/ replicate m^{-2})

Orthoptera species/life stage	Crossfield	Headland	Z value and sig.*
Species richness/100m/replicate (max-min)	0.57 (0.65)	1.25 (0.90)	-2.38, P<0.05
Overall abundance (all life stages and species)	34 (0.01)	939 (0.02)	-1.68, NS
Chorthippus spp. nymphs	13 (0.00)	326 (0.01)	-1.04, NS
Chorthippus albomarginatus adults	11 (0.00)	69 (0.00)	-0.22, NS
Chorthippus brunneus adults	9 (0.00)	333 (0.01)	-1.37, NS
Chorthippus parallelus adults	1 (0.00)	193 (0.00)	-1.34, NS
Metrioptera roeselii adults	0 (0.00)	8 (0.00)	NT
Pholidoptera griseoaptera adults	0 (0.00)	4 (0.00)	NT
Tetrix subulata adults	0 (0.00)	6 (0.00)	NT

* significant differences between the density of selected species/life stages or species richness on crossfield and headland footpaths (Mann-Whitney *U* test), NS = no significance, NT = data not tested due to a lack of sightings

Fig. 2. Headland (field edge) footpath on the east side of a hedgerow. See also PLATE I.

Sampling of Orthoptera populations.—Transect methods for ascertaining Orthoptera abundance have been developed from butterfly transect techniques used for monitoring purposes (Pollard & Yates 1993) and are effective for sampling grasshoppers in short, open swards (< 50 cm in length) where adult densities are < 2 grasshoppers m^{-2} (Gardiner *et al.* 2005a). Orthoptera density estimates produced using transects are comparable to controlled techniques such as box quadrats, therefore the method can be used to reliably estimate Orthoptera density in the linear footpaths in this study (Gardiner & Hill 2006a). However, species richness estimates produced from transect counts need to be viewed with caution: surveyors tend to miss bushcricket species such as Roesel's bushcricket, *Metrioptera roeselii*, and the long-winged conehead, *Conocephalus discolor*, due to their ability to escape or hide from the observer before identification has been confirmed (Gardiner & Hill 2006a). The behavior of the sampler may also affect counts, as the transect walker is constantly on the move (except for short stops to record sightings) and unable to search the vegetation in any detail (Gardiner & Hill 2006a).

In the study reported in this paper fixed transects were utilised to survey Orthoptera populations on the linear footpaths (transect length for each replicate is shown in Table 1). Each transect was walked at a slow strolling pace (2 km/h) and the number of orthopterans 'flushed' in a 0.5-m strip in front of the observer were counted (Isern-Vallverdu *et al.* 1993, Gardiner *et al.* 2005b). To determine which areas of crossfield footpaths Orthoptera were using, the author subtotalled the numbers of individuals counted < 10 m from the field edge and from the center of the crop (> 10 m from the field edge).

It was possible to accurately sort adult grasshoppers and bushcrickets to species on sight. However, grasshopper nymphs are difficult to sort to species visually (Richards & Waloff 1954). In preliminary surveys of grasslands in the Chelmsford area in previous years (1999-2001), only three *Chorthippus* species were identified, therefore, nymphs on the transects could be confidently assumed to belong to this genus. Thus any nymphal individuals 'flushed' were recorded as *Chorthippus* spp. nymphs. Six transect surveys were undertaken in each replicate in 2006 (survey dates: 16/06, 29/06, 13/07, 27/07, 10/08, 22/08). All transect surveys were undertaken in similar weather conditions (>17°C, sunny) and at the same time of day (between 0900 and 1600).

Sampling of sward height.—Sward height is particularly important for grasshoppers, which can display a preference for swards of a certain length (100 to 200 mm for *Chorthippus* grasshoppers, Gardiner *et al.* 2002). Vegetation height was recorded (in mm) in this study by measuring the height of the grass at random locations using a meter rule. A drop-disc method was not used as the presence of uneven bare earth where the disc would not settle evenly would prevent an accurate estimation of sward height. Twenty sward-height measurements were randomly taken from each footpath replicate on 29 June and 10 August 2006.

Statistical analysis.—The author calculated orthopteran density m^{-2} in all replicates to determine whether Orthoptera preferred crossfield or headland footpaths. The overall density for each replicate over the monitoring period was calculated by dividing the total number of individuals by the total area searched throughout the whole season (e.g., for a 100 × 0.5 m transect, the area searched is 50 m^2 on each survey occasion = 300 m^2 searched over the six surveys) and then dividing that by the number of surveys to produce an average density. Due to the generally low densities of Orthoptera recorded (< 0.5 individuals m^{-2}), the author was only able to statistically analyse the total density of Orthoptera for all species combined (not of individual species), density of *Chorthippus* spp. nymphs and the adult density of the three most abundant species (lesser marsh grasshopper *Chorthippus albomarginatus, C. brunneus* and meadow grasshopper *Chorthippus parallelus*) in the different footpath types.

Counts of Orthoptera in grassland can be very variable and many zero counts are often recorded and this influences the strategies appropriate for the analysis of data (Gardiner *et al.* 2005a). In swards of variable structure it is safer to use distribution-free nonparametric statistics (Mann-Whitney *U* test or similar) to avoid any misinterpretation of inferences drawn after analysis (Gardiner *et al.* 2005a). Therefore due to the extremely heterogeneous vegetation structure of the footpaths, the author decided to use nonparametric statistics.

To examine whether footpath type affected total Orthoptera density and the density of *Chorthippus* spp. nymphs, *C. albomarginatus*, *C. brunneus* and *C. parallelus* adults, a Mann-Whitney *U* test was applied (Heath 1995). The test was calculated using the density of Orthoptera in each replicate for each footpath type. Species richness/100 m/replicate was compared for crossfield and headland footpaths. Sward height was compared for each footpath type by undertaking a Mann-Whitney *U* test between sward heights in each replicate type (mean sward height was calculated for both surveys, the median value was taken between mean sward height for two surveys). An important relationship was suspected between sward height and species richness: Spearman's Rank Correlation was used to test this (Heath 1995). All statistical analyses were performed using SPSS Version 14 (SPSS 2005).

Results

Six Orthoptera species were recorded on the farmland footpaths in this study (both footpath types combined), the most numerous being the grasshopper *C. brunneus*, which formed 54% of adult sightings (Table 2). *C. parallelus* and *C. albomarginatus* were less frequently recorded (31% and 13% of adult sightings respectively). Bushcrickets (*M. roeselii* and the dark bushcricket *Pholidoptera griseoaptera*) and groundhoppers (slender groundhopper *Tetrix subulata*) were recorded very rarely during the study. All six species were found on headland footpaths, whereas only three species were recorded from crossfield rights of way (the three *Chorthippus* grasshoppers). Indeed, species richness differed significantly (Mann-Whitney *U*, Z = -2.38, p<0.05) between crossfield and headland footpaths (Table 2). Species richness was significantly correlated with sward height in this study (r_s = 0.66, p<0.05), higher numbers of species being recorded in the taller vegetation of the headland footpaths (Fig. 3). Sward height differed significantly (Mann-Whitney *U* test, Z = -2.72, p<0.01) between crossfield (median sward height/replicate = 15 mm, min/max = 1 to 50 mm) and headland (median sward height/replicate = 122 mm, min/max = 69 to 176 mm) footpaths.

A total of 939 individuals (of all species and life stages combined) were observed on transects on headland footpaths, which is 97% of the total number of Orthoptera recorded. All species were more numerous on the headland footpaths (Table 2), although there were not significantly higher densities (of *Chorthippus* spp. nymphs and *C. albomarginatus*, *C. brunneus* and *C. parallelus* adults) recorded when compared to the crossfield footpaths (Table 2). Overall densities of Orthoptera, of all life stages and species combined, were also not significantly higher on the headland footpaths when compared to crossfield rights of way, although high abundance was observed for three headland replicates situated on the eastern side of hedgerows running approximately north to south (Fig. 4).

On the crossfield footpaths, 29 of the 34 individuals observed were sighted < 10 m from the field edge (85% of individuals recorded on crossfield footpaths). Only *C. brunneus* (three adults) and *Chorthippus* spp. nymphs (two nymphs) were recorded from the center of the crop (> 10 m from field edge).

Discussion

The most abundant Orthoptera species on the farmland footpaths in this study was *C. brunneus*, unusual because in the Chelmsford area it was rarely recorded in a previous study of agricultural habitats such as hay meadows, heavily fertilised pastures and arable fields (Gardiner *et al.* 2002). The abundance of this species on footpaths may be due to its preference for habitats with patches of exposed soil (Marshall & Haes 1988), conditions frequently found in this study due to the wear and tear of walker's feet causing erosion of the vegetative cover (Liddle 1997). Exposed soil tends to be hotter than earth covered by vegetation (Key 2000), which is especially important for warmth-loving grasshoppers, which may bask on the warm soil. Patches of bare earth are also suitable oviposition sites for mesophilous species such as *C. brunneus* and *C. parallelus,* which lay their eggs in the superficial layers of the soil, although excessive trampling may create compaction which would be hard for ovipositors to penetrate. However, it seems that the footpaths in this study were infrequently utilised by walkers (only two walkers seen throughout 15 + hours of surveying). Low recreational usage in the study of Alpine pasturelands by Voisin (1986) did not appear to affect the numbers or diversity of Orthoptera, reductions in both parameters only occurring where trampling pressure was intensive.

Bushcrickets such as *M. roeselii* and *P. griseoaptera* were rarely observed and were restricted to headland paths (Table 2). Possible reasons for their low abundance could be the short swards of the footpaths in this study (< 200 mm, Fig. 3) due to the two-cut sum-

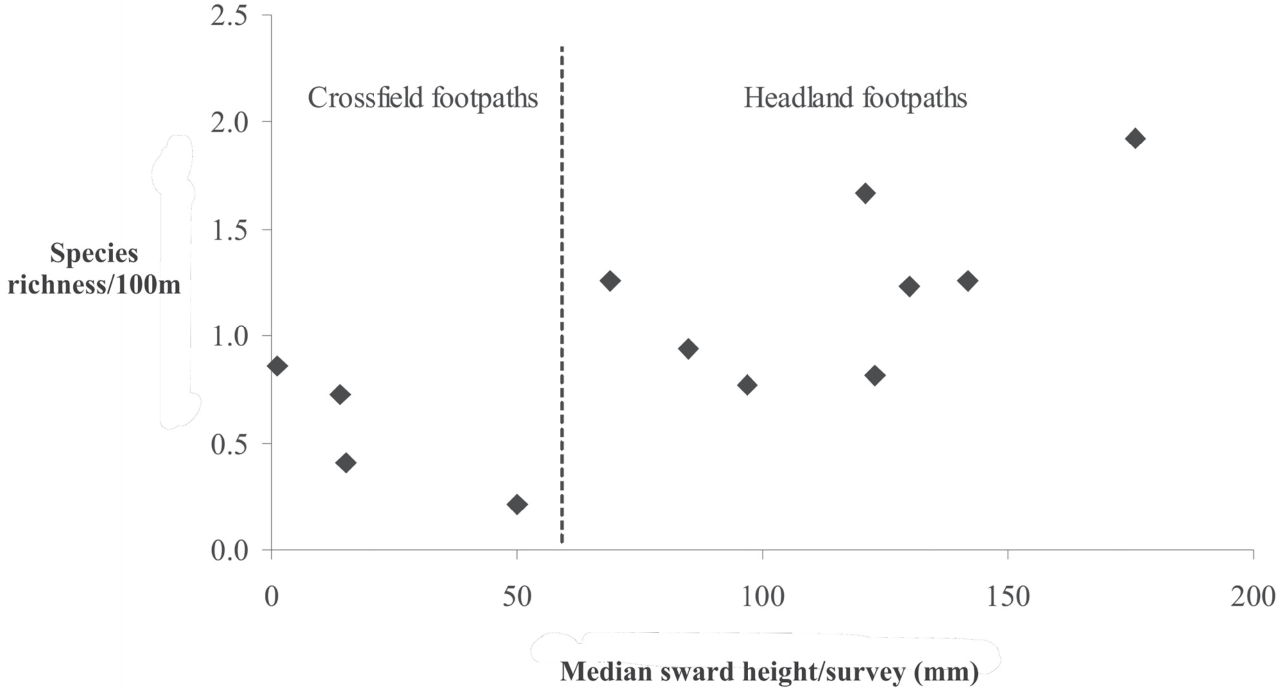

Fig. 3. Relationship between sward height and Orthoptera species richness on farmland footpaths in the Chelmsford area of Essex, UK (each data point is a replicate).

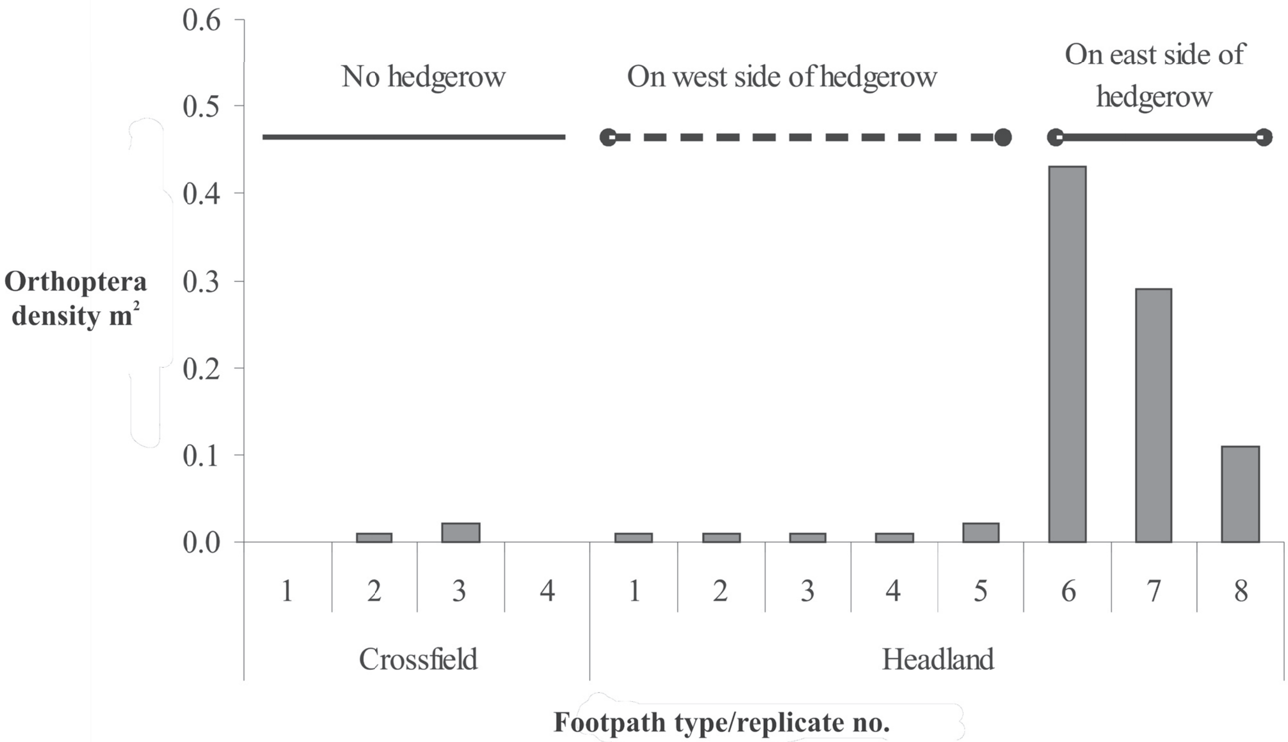

Fig. 4. Density m^{-2} of Orthoptera (all life stages and species combined) in each replicate for crossfield and headland footpaths; note the high abundance of Orthoptera on the east side of hedgerows.

mer mowing regime adopted by the landowner under the HMS. Bushcrickets such as *M. roeselii* require tall vegetation (Marshall & Haes 1988), typically established in the absence of regular mowing.

It is likely that the two-cut mowing regime adopted on the footpaths in this study may have caused mortality of Orthoptera. Gardiner & Hill (2006b) showed that Orthoptera of all developmental stages were killed by rotary cutting blades or contact with machinery during the process of hay and silage mowing in midsummer. A species such as *C. parallelus* is known to inhabit the ground zone (< 20-cm sward height) of hay meadows, where it primarily exhibits resting and basking behavior (Gardiner & Hill 2005); this makes it vulnerable to disturbance and mortality from cutting blades which pass through the vegetation at a height of approximately 10 cm. However, most headland footpaths were abutted by 2, 4 and 6-m wide grass margins established under the ELS, and these strips could have provided adequate buffer zones into which Orthoptera, displaced due to the disturbance caused by cutting, could take refuge.

Headland footpaths, however, provide habitat for a higher number of species than crossfield rights of way (6 *vs* 3 species, Table 2) perhaps due to the absence of annual ploughing, which allows species to breed and sustain populations. Eggs of mesophilous species may be destroyed by ploughing of crossfield footpaths, which pushes them deep into the soil causing hatching failure (Lockwood 2004, Gardiner *et al*. 2005b). Marshall *et al*. (2006) also noted an absence of Orthoptera from the center of fields in their study of insects in southern England. Bushcrickets such as *M. roeselii* and *P. griseoaptera* were absent from the crossfield rights of way and are particularly unlikely to colonise this type of footpath, due to the absence of well-established tall vegetation that may be present on field edge rights of way. Annual ploughing of the crossfield footpaths leads to the establishment of plant communities dominated by annual species such as Knotgrass *Polygonum aviculare* with very infrequent grass cover, conditions unlikely to be favorable for completion of the life cycle of Orthoptera native to the UK. Indeed, in this study, species richness was correlated significantly with sward height, greater species richness being evident in the taller vegetation of the headland footpaths (Fig. 3).

The limited number of orthopterans recorded from crossfield footpaths (Table 2) were mostly sighted < 10 m from the field edge, suggesting that they could have been utilising the high occurrence of bare earth (Fig. 1) for basking purposes, whilst temporarily absent from nearby headlands. It suggests also that they were not using the footpaths to disperse across the fields, which contained tall and dense crops of wheat and barley, unlikely to be favorable for Orthoptera in the UK. Therefore, the ephemeral nature of crossfield rights of way and the patchiness of the vegetation cover probably preclude their use as corridors by Orthoptera through all but the smallest arable fields (fields were large in this study; maximum field size of 33 ha). However, five replicates of the headland footpaths had very low abundance of Orthoptera, leading to similar overall densities to crossfield footpaths for all three *Chorthippus* species in this study (Table 2).

The three sections of headland which were situated on the east side of a hedgerow boundary, provided a more sheltered, less windy microclimate, than the footpaths located on the west of mature hedgerows, which were exposed to the prevailing westerly wind (Fig. 4). Orthoptera species may have benefited from the shelter provided by hedgerows and achieved higher densities in the calm conditions provided on the leeward eastern side of hedgerows and their associated banks. Most orthopteran species in the UK do not fly strongly and only achieve flights over short distances of 2 to 3 m (Marshall & Haes 1988), but it seems they are still likely to favor sheltered conditions, similarly to flying insects such as butterflies (Dover *et al*. 1997), particularly as the dispersal of some species such as *C. parallelus* is reduced at high wind speeds (Gardiner 2006).

The eastern (leeward) side of hedgerows may also have more direct solar radiation early in the day (from sunrise to 1200 hours) in the late spring and summer, in comparison to the western (windward) side which will receive direct sunlight later in the day (1200 hours onwards). This places individuals on the eastern side of hedgerows at a distinct advantage as they are able to begin feeding and moving earlier in the day than those on the shady western side. Indeed Orthoptera species seem to prefer sheltered 'suntrap' sites as habitat (Marshall & Haes 1988).

The results presented in this paper must be viewed with some caution due to the limitations of the recording method which can underestimate species richness of Orthoptera (Gardiner & Hill 2006a). The low abundance of bushcrickets in this study may be due to the inefficiency of the sampling method and not the actual scarcity of the insects. However, transect counting does give accurate estimations of orthopteran abundance and was used in this study due to the limited time available for surveying. The author suggests that surveys should be undertaken in several years and at different sites to fully detail the orthopteran assemblages of crossfield and headland footpaths. It might also be interesting to examine the precise effect hedgerow shelter has on Orthoptera.

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